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For You

Partial Discharge Monitoring Technology

By

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Technical Support Dept.

TechnoMaster Co.

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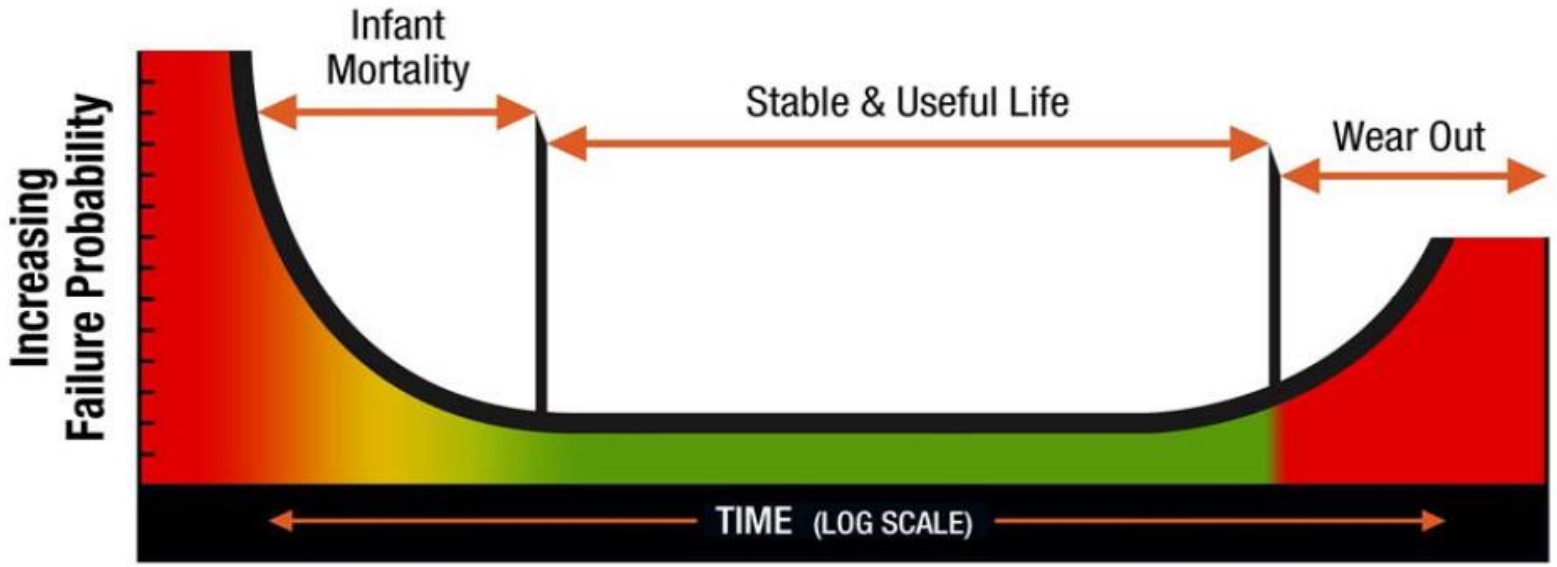
Why Predictive Maintenance



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Preventive (routine) maintenance is

(**Time** – based maintenance)

But

Predictive maintenance is

(**Condition** – based maintenance)

So why you lose your time ?

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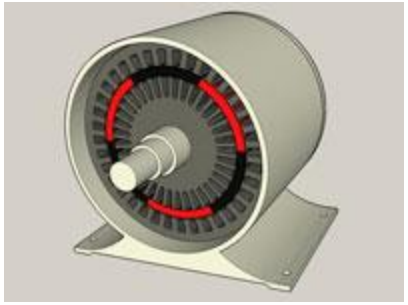
Most **PdM** inspections are performed while equipment is **in service**

PdM utilizes **nondestructive** testing technologies

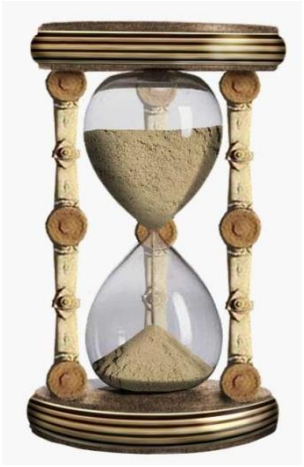
PdM

Save your



Machine

+



Time

+

Money

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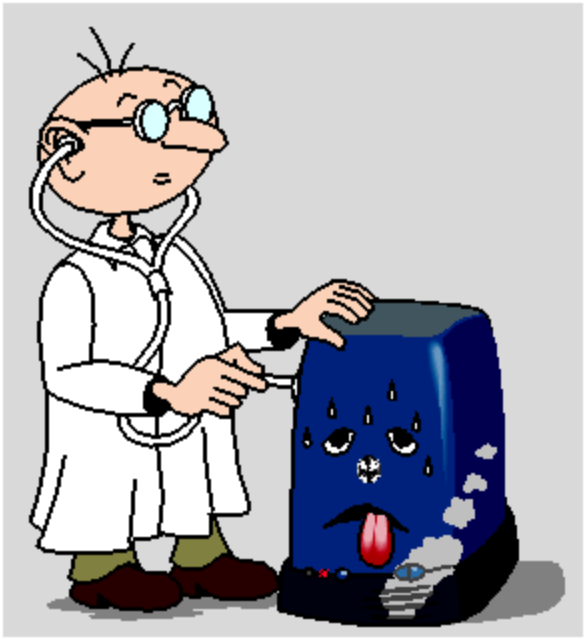
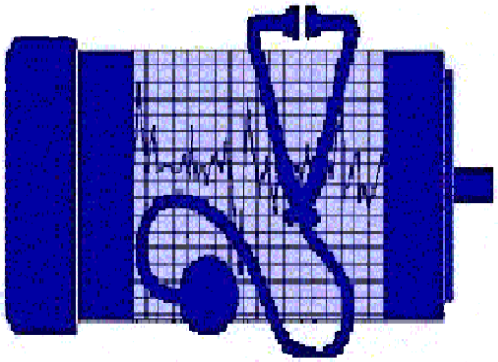
Monitoring & Diagnostics



What is
M&D

Monitoring & Diagnostic



A two “complementary” steps approach

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M&D

Monitoring: On-Line techniques and devices to detect abnormal conditions

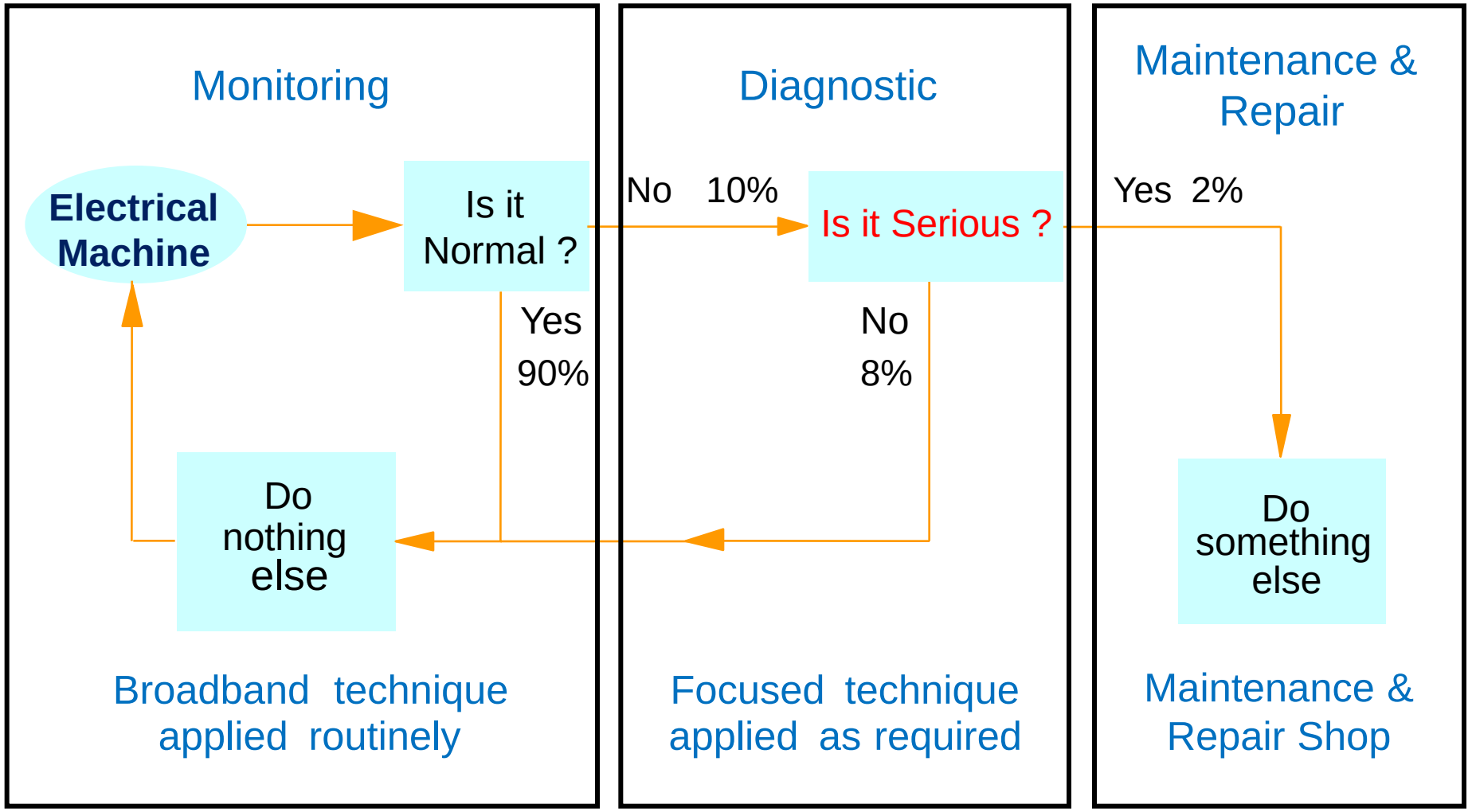
Monitoring function: is to avoid unexpected machine failure and insure continuous normal operation

M&D

Diagnostic: Application of On-Line **and** Off-Line devices & techniques to confirm and determine the exact nature of the anomaly

Diagnostic function: is to minimize unwanted downtime by making accurate condition assessment when anomalies occur

Monitoring vs. Diagnostics



Cigre Report No. 227, Life Management Techniques for Power Transformers. WG A2.18

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Partial Discharge

PD

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The Partial Discharge (**PD**) considered as a **Disease** which affect on your equipments

((Gen. , Motor , Transformer , GIS ,Cables))

through the **insulation** causing early destruction of your equipments before it's expected age

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What Is Partial Discharge (PD) ?

Partial Discharges (PD) are ionizations or "sparks" occurring in voids or gaps within, or on the surface of, insulation, without any insulation **breakdown**.

Origin of the term by source of activity

INTERNAL = PD vs. EXTERNAL = Corona

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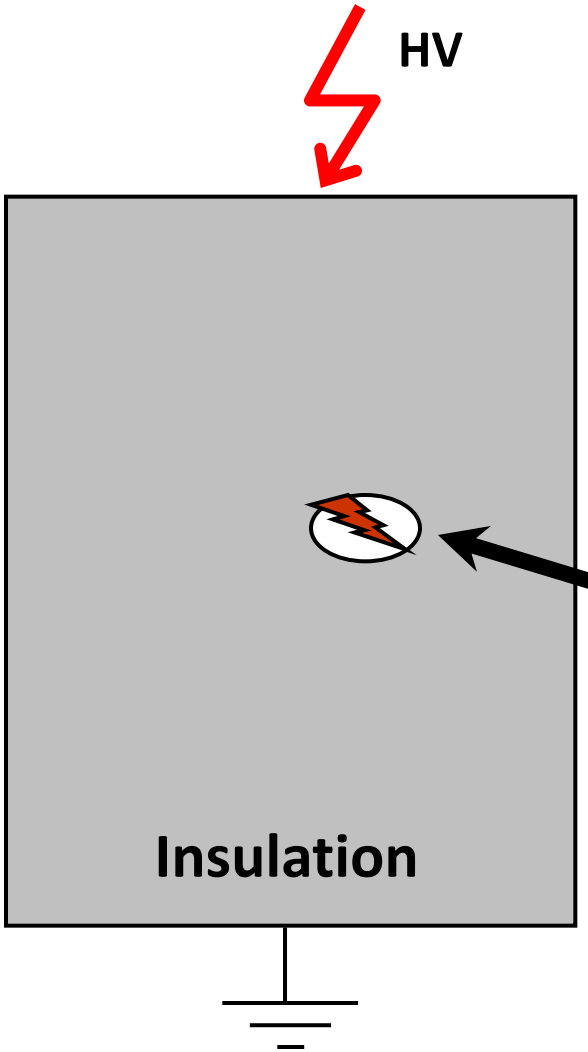


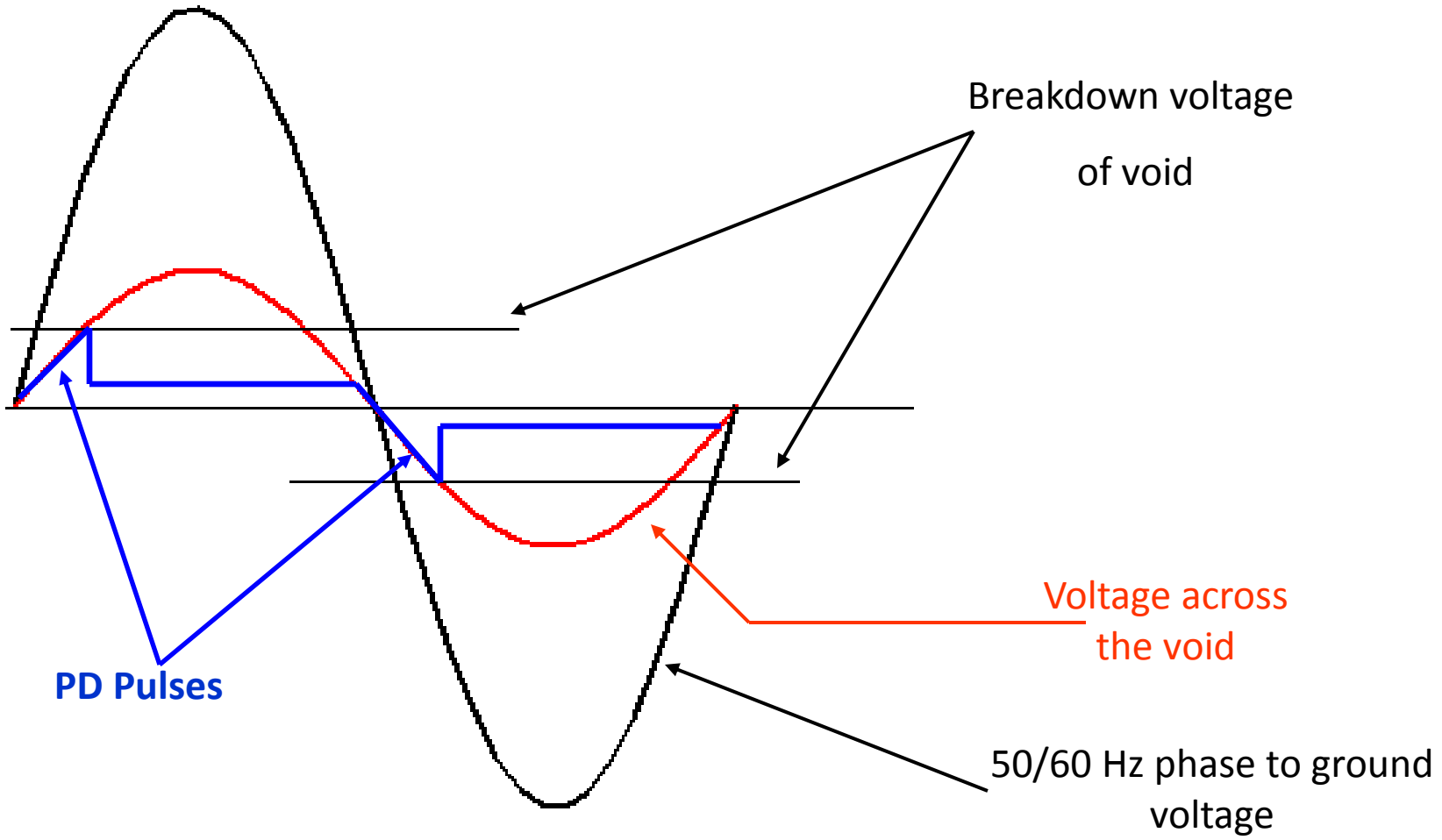
It's Occur Where :

air (3 kV/mm) < solid insulation (~300 kV/mm)

The discharge occurs in the void itself ,

Not full breakdown

So PD creates small local ionises



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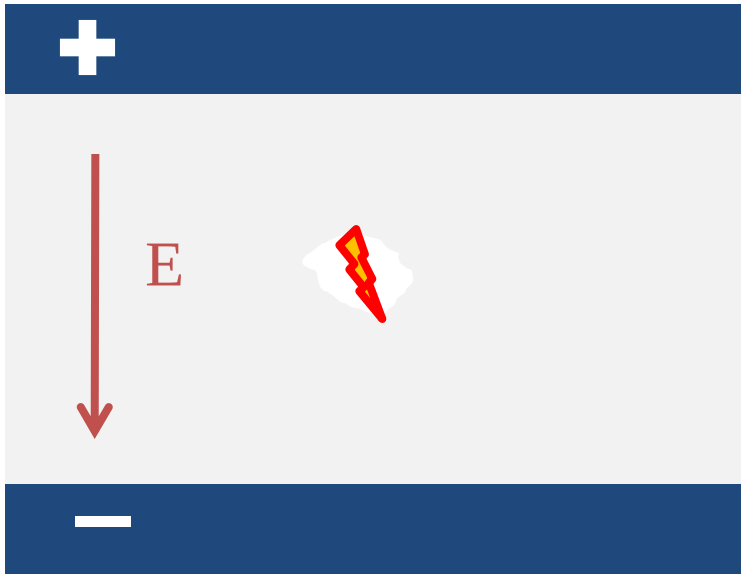
Steps of PD Streamer Process

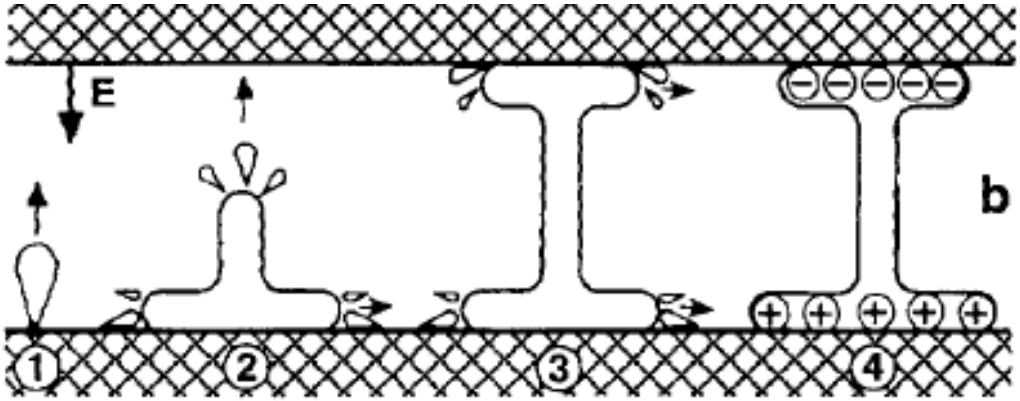
HV Conductor

Insulation

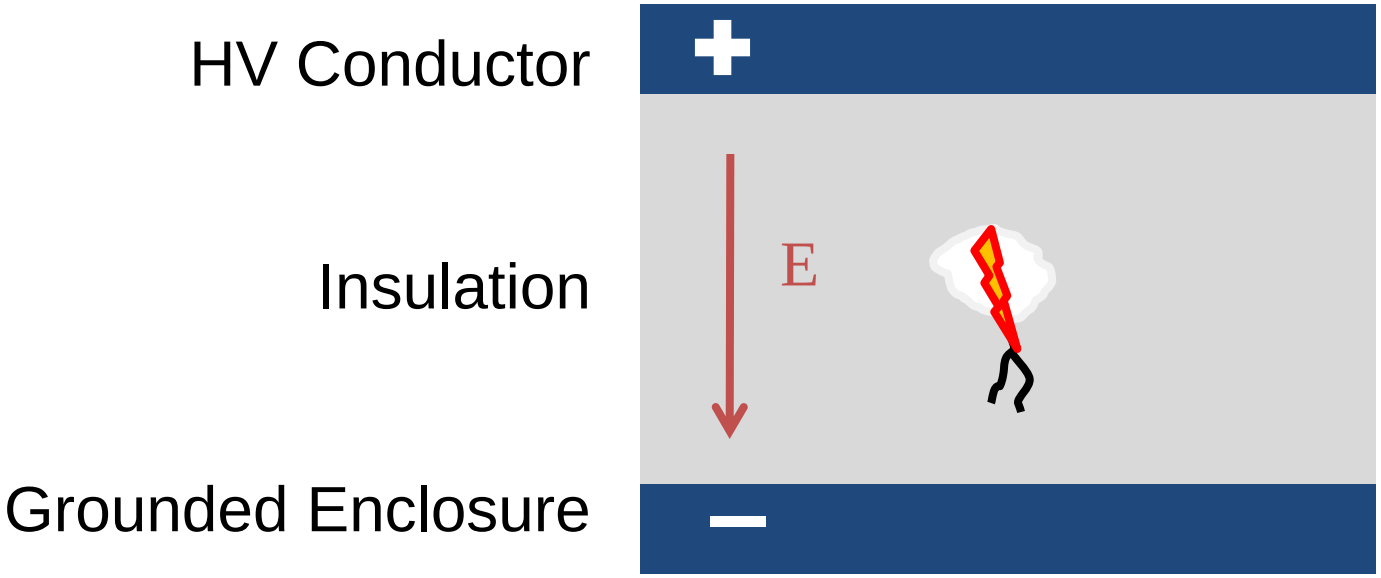
Grounded Enclosure



Streamer Discharge Process



Void Turning into Treeing



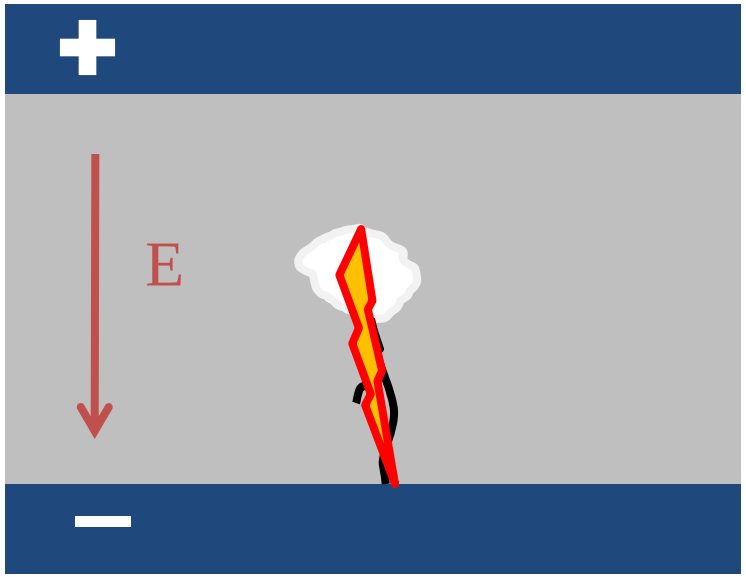
After a certain period depending on **material parameters** and discharge conditions cumulated PD energy cracks the surface of the void and initiates treeing PD.

PD Close to Breakdown

HV Conductor

Insulation

Grounded Enclosure



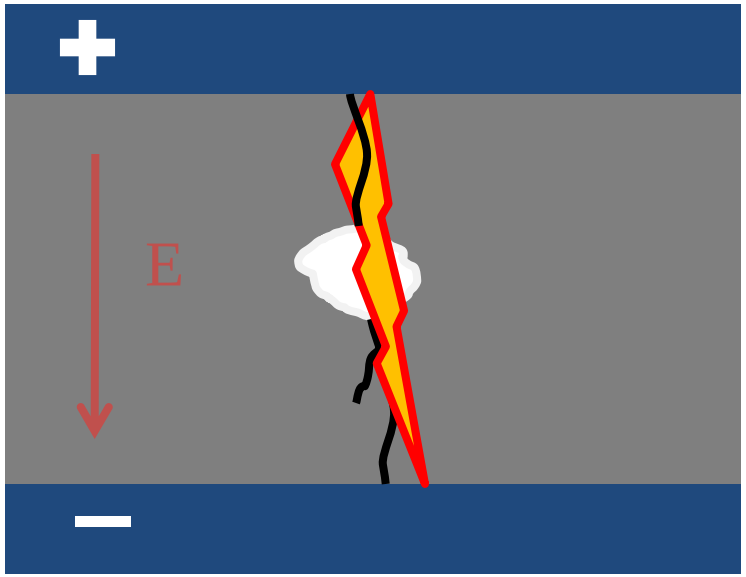
Treeing PD grows dynamically and reaches one of the electrodes.

Final Breakdown

HV Conductor

Insulation

Grounded Enclosure



Finally treeing PD **breaks up material** and short circuits the whole isolation distance, the final breakdown takes place.

Causes of partial discharge in Generators

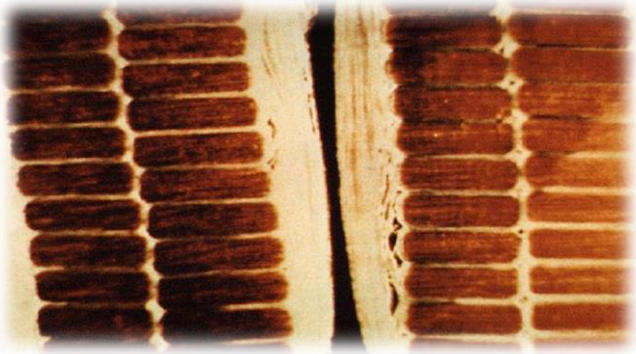
PD a Symptom or Cause of Many Failure Processes

Internal

- **Thermal Deterioration**

Such as: overloads, defective cooling, unbalanced phase voltage and poor design

- **Load cycling**
- **Inadequate bonding**

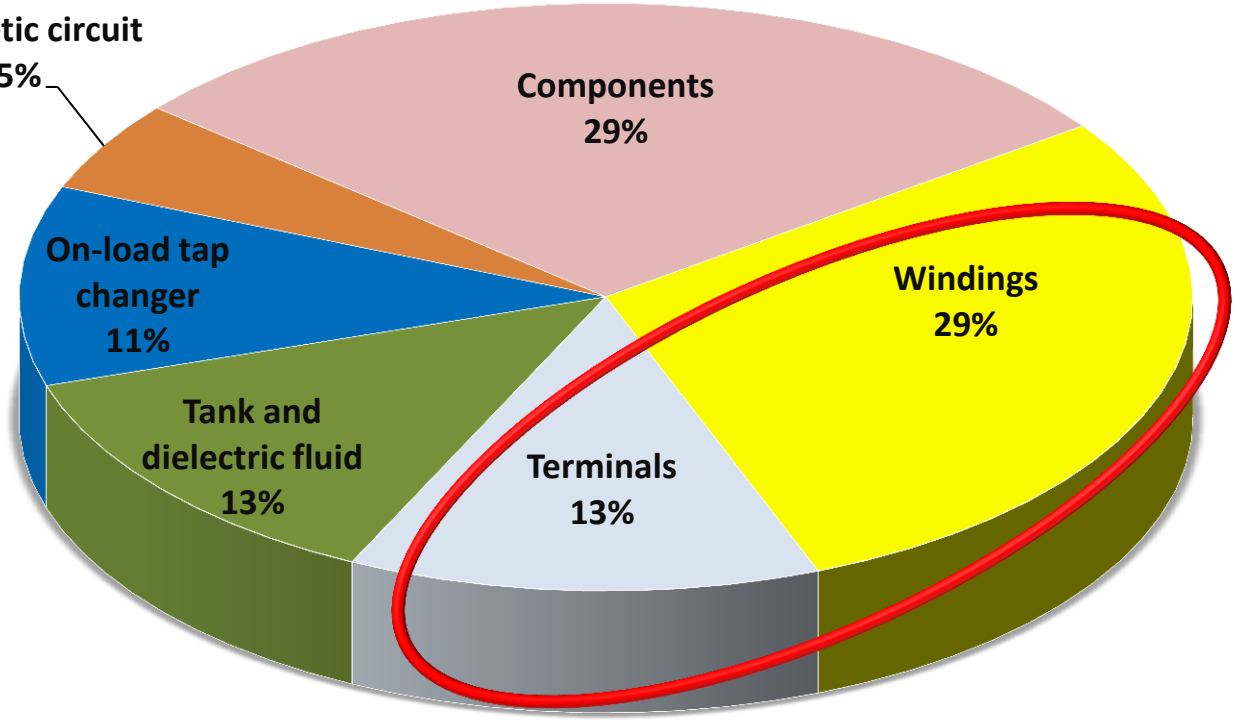


Surface

- **Loose windings**
- **Slot discharge**
- **Contamination**
- **Inadequate spacing**

Causes of partial discharge in Transformers

Percentage of Failures in Power Transformers



Source: Cigré WG 12.05 reliability study circa 1983

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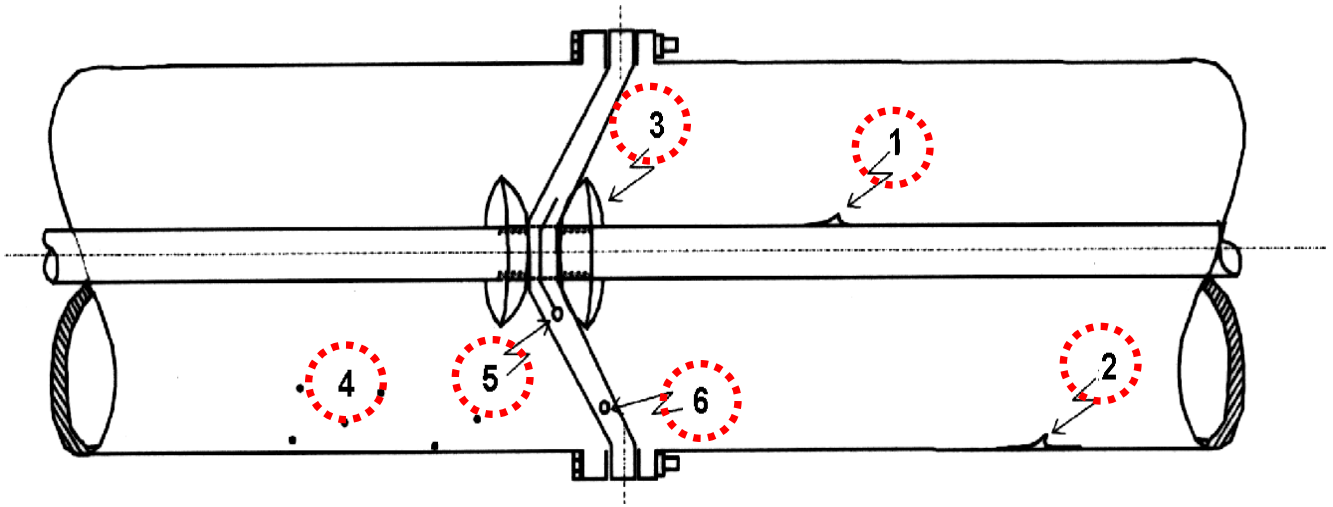
Causes of partial discharge in GIS



1- protrusions on conductor (fixed particle)

2- protrusions on enclosure (fixed particle)

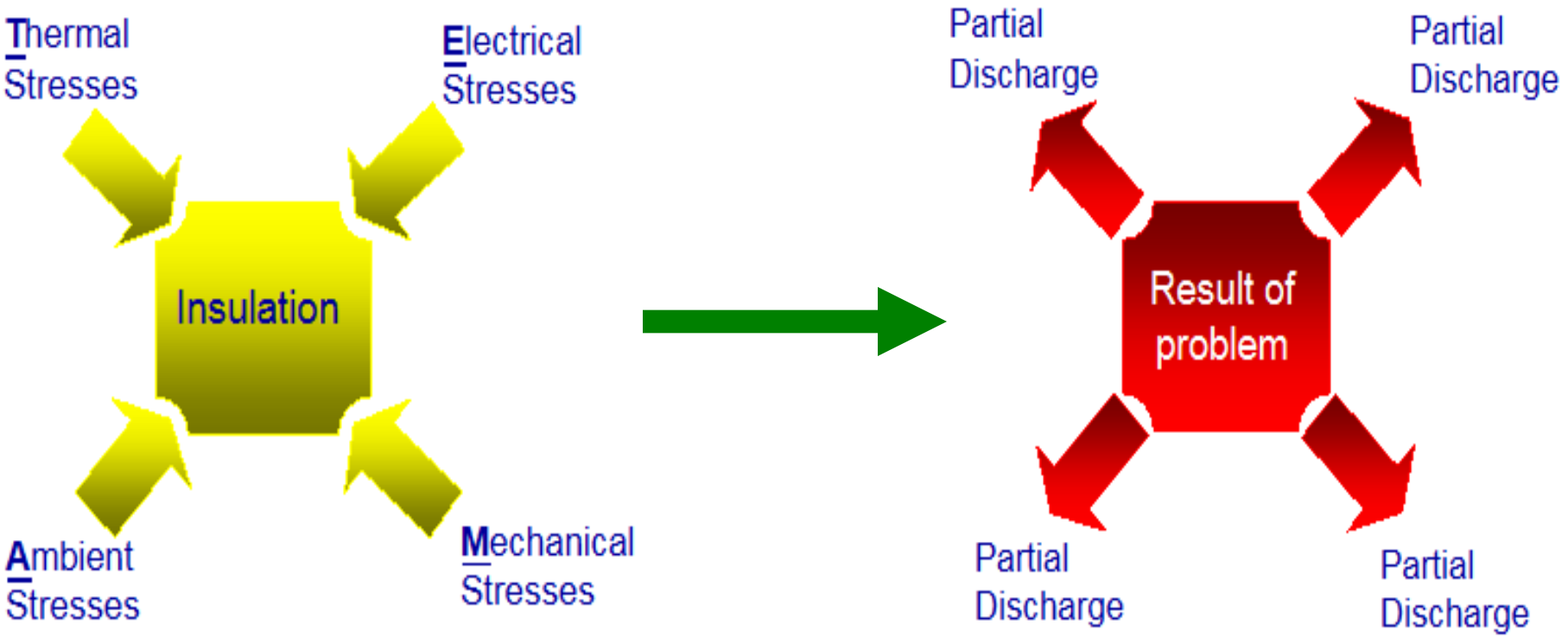
3- floating parts (bad galvanic contact)

4- free particles on live parts and insulators

5- voids (delamination) between screens and insulation

6- voids and treeing in insulation

General sources of Partial Discharge?



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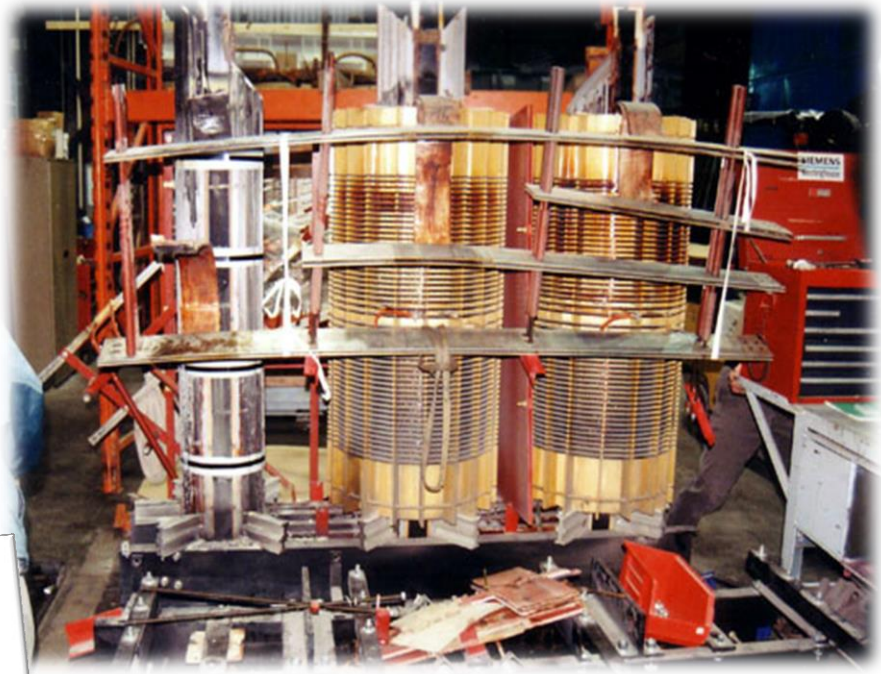
Motor Stator Winding Failure


Yale


SIEMENS

The following movie will show us real PD pulses occurs within the insulator

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Why Monitor PD?

PD monitoring enables you to do the 3 "**Rights**" of maintenance:

the **Right** maintenance on
the **Right** machines at
the **Right** time

5 Advantages to monitor PD :

1. ***Avoid unnecessary rewinds on older machines by maximizing the operating hours***

Why rewind if the winding is still in good shape?

2. ***Extend the Lifetime of Your Winding Insulation***
3. **Extend up-time between outages**
4. ***Reduce Capital Costs***
5. ***Maximize Production Revenue***

More 5 Advantages to monitor PD :

6. *Simple, Safe, and Inexpensive to Test*
7. *Find problems on new machines which may still be under warranty*
8. *Confirm Effectiveness of Repairs*
9. *Non-Destructive Test*
10. *Accomplish all this while the machine remains in operation (On-Line)*

PHYSICS OF PD DETECTION

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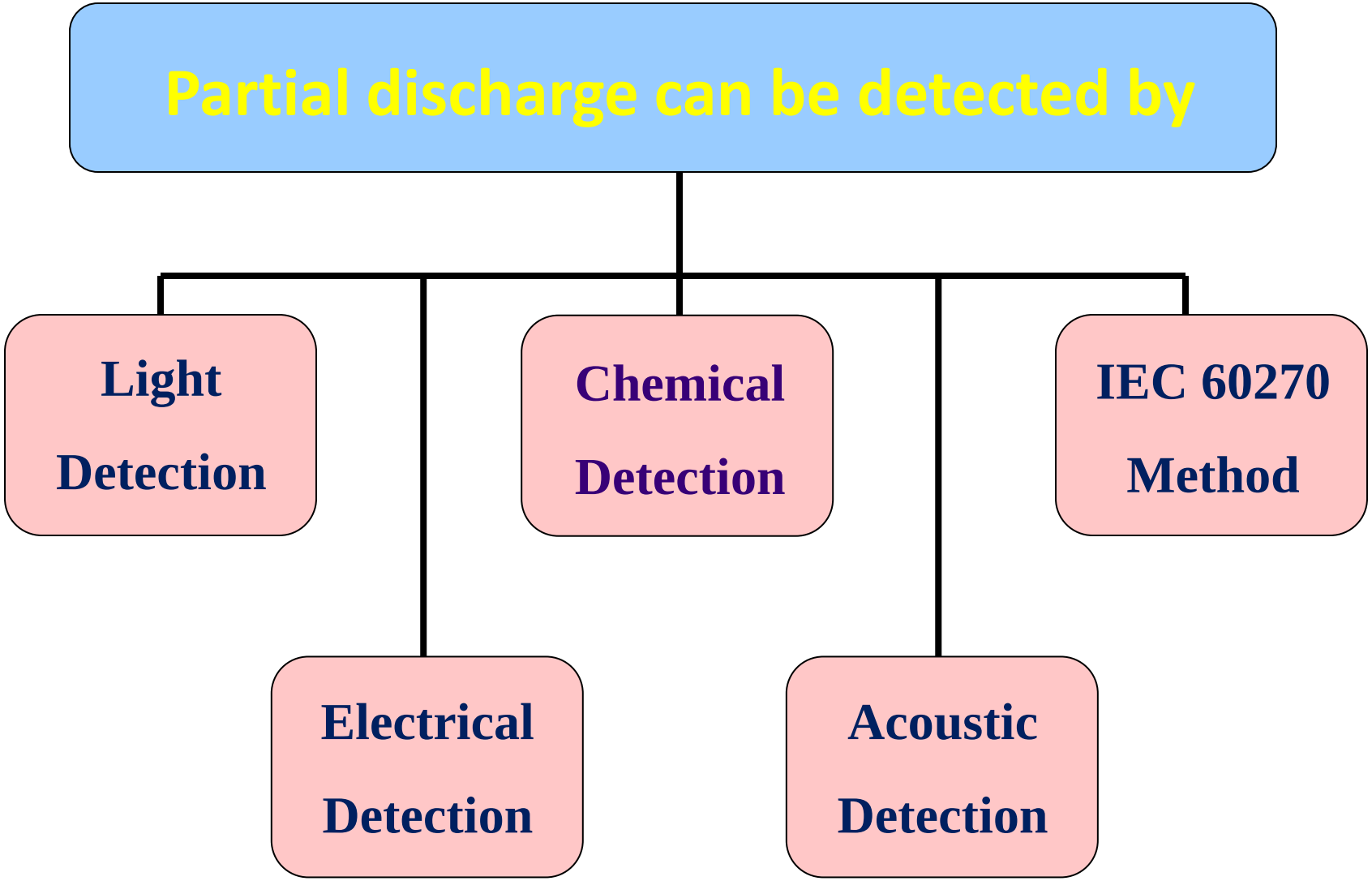

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Light Detection

Method: high sensitivity photomultiplier near HV parts.

- **most sensitive**
- **radiation in the UV band**
- **strongly absorbed by glass and SF6 - powerful laboratory technique for basic research**
- **not practical for online monitoring of GIS**

Chemical By-products

Method: Chemical reagent tubes or gas analyser.

- **immune to electrical interference**
- **for a steady discharge, diagnostic gas should rise to a level where it can be detected**
- **small volume lab tests, a 10-15pC discharge can be detected after some tens of hours**
- **insensitive due to large volumes of gas in GIS**
- **Shows total integrated equivalent PD over time (similar to DGA)**
- **although still being studied - some success in smaller GIS gas compartments**

Acoustic Emission

Method: Accelerometers or Ultrasonic microphones

- **sensitive, particularly for particles on chamber floor**
- **features of the acoustic signal can infer the shape and movement of a particle**
- **the measurements can be made external to the GIS**
- **commonly used during site acceptance testing, easy to use**
- **accurate location by finger printing along GIS or by time of flight using two sensors**
- **attenuation of signal is high, particularly on barriers so unsuited for detection of void type defects**
- **often used to backup UHF technique or where UHF cannot be applied**
- **not suited to permanent monitoring as too many sensors would be required**

Acoustic Emission - Detection

Pistol for simple location

More sophisticated analyser

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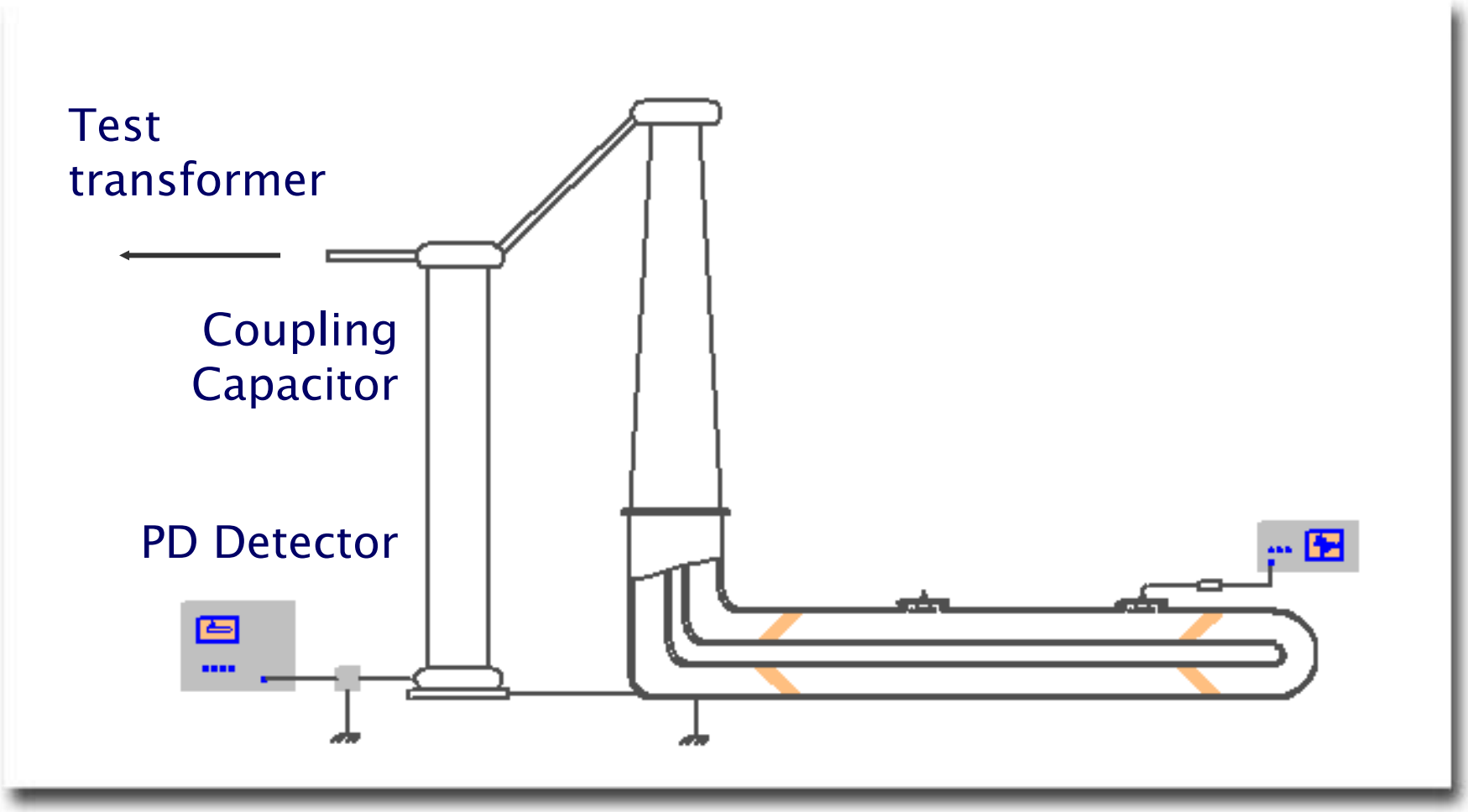
Conventional IEC270 Method

Method: Coupling capacitor connected to HV part

- **industrial standard**
- **calibrated in PC**
- **for maximum sensitivity, requires completely shielded test arrangement**
- **total capacitance of GIS is high and must be divided into sections for tests**
- **no means to locate discharge**
- **no coupling capacitor on GIS, hence method cannot be used for in-service measurements**

Conventional IEC270 Method



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Electromagnetic Detection

Method: Electric field sensor near HV parts

- **signal is easily detected if noise can be eliminated**
- **for GIS the UHF band offers very high sensitivity to all defect types and good noise rejection**
- **allows relative PD amplitude and pulse activity to be measured**
- **signal contains information on the type of defect producing the PD so defect classification is possible**
- **time of flight measurement using two sensors allows accurate location of discharge**
- **high sensitivity of field sensors means that large sections of GIS can be monitored effectively**
- **preferred method for site testing of EHV GIS**

CIGRE Investigation (1992)

Cigre conducted an evaluation of the various available PD detection methods in 1992:

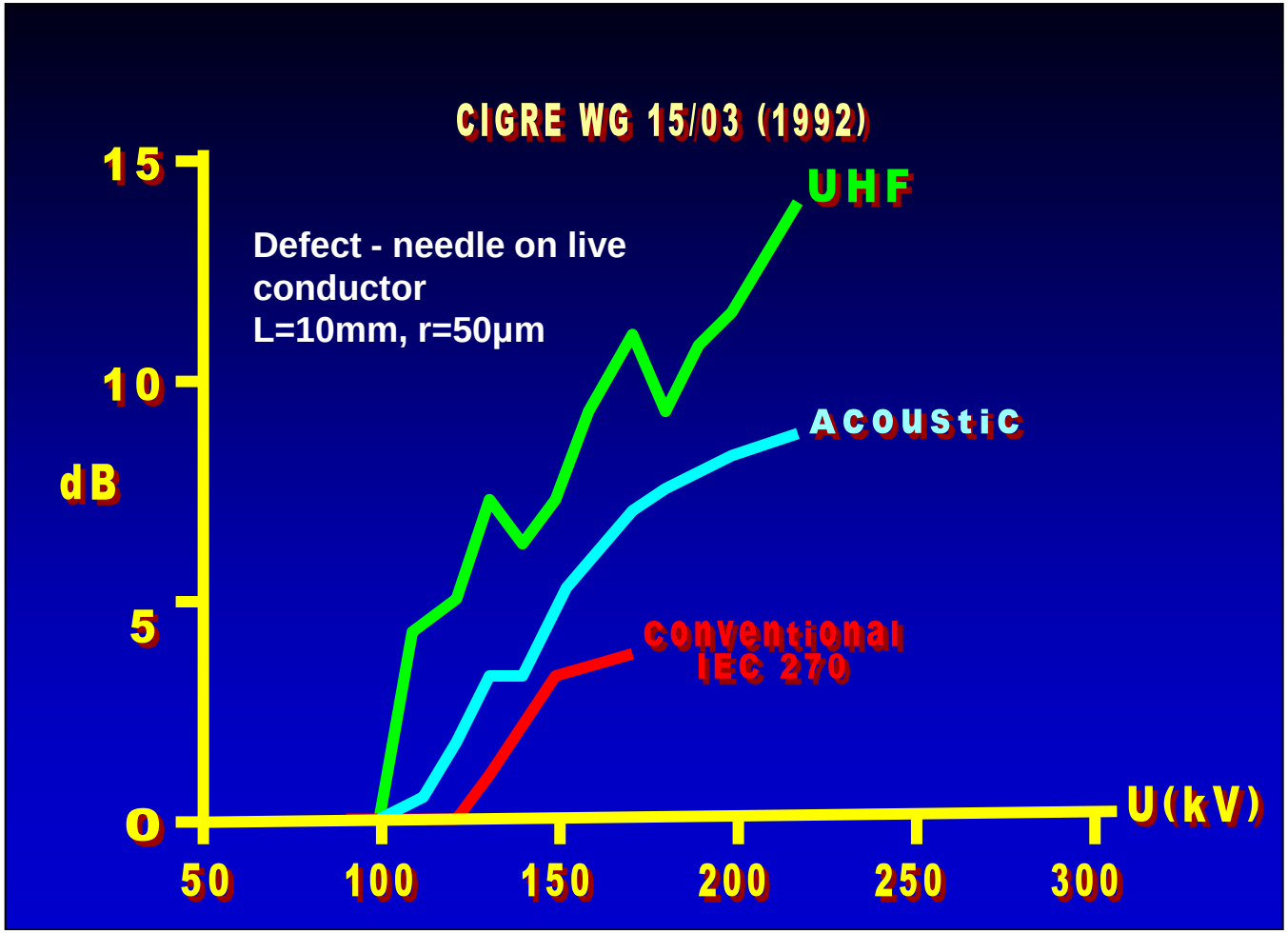
- **conventional PD to IEC270**, with either a standard detector at 1MHz or the PRPD evaluation system at 200MHz
- **UHF** using an internal coupler up to 1500MHz
- external **acoustic** emission sensor at 34kHz
- **chemical** using detector tubes

CIGRE Investigation (1992)

The study concluded:

- acoustic, conventional and UHF techniques show good sensitivity
- acoustic methods are non-intrusive but attenuation of signal across barriers and along chambers is high
- conventional measurements need external coupling capacitor and cannot be used on GIS in-service
- **UHF technique suitable for in-service monitoring**

CIGRE Investigation (1992)



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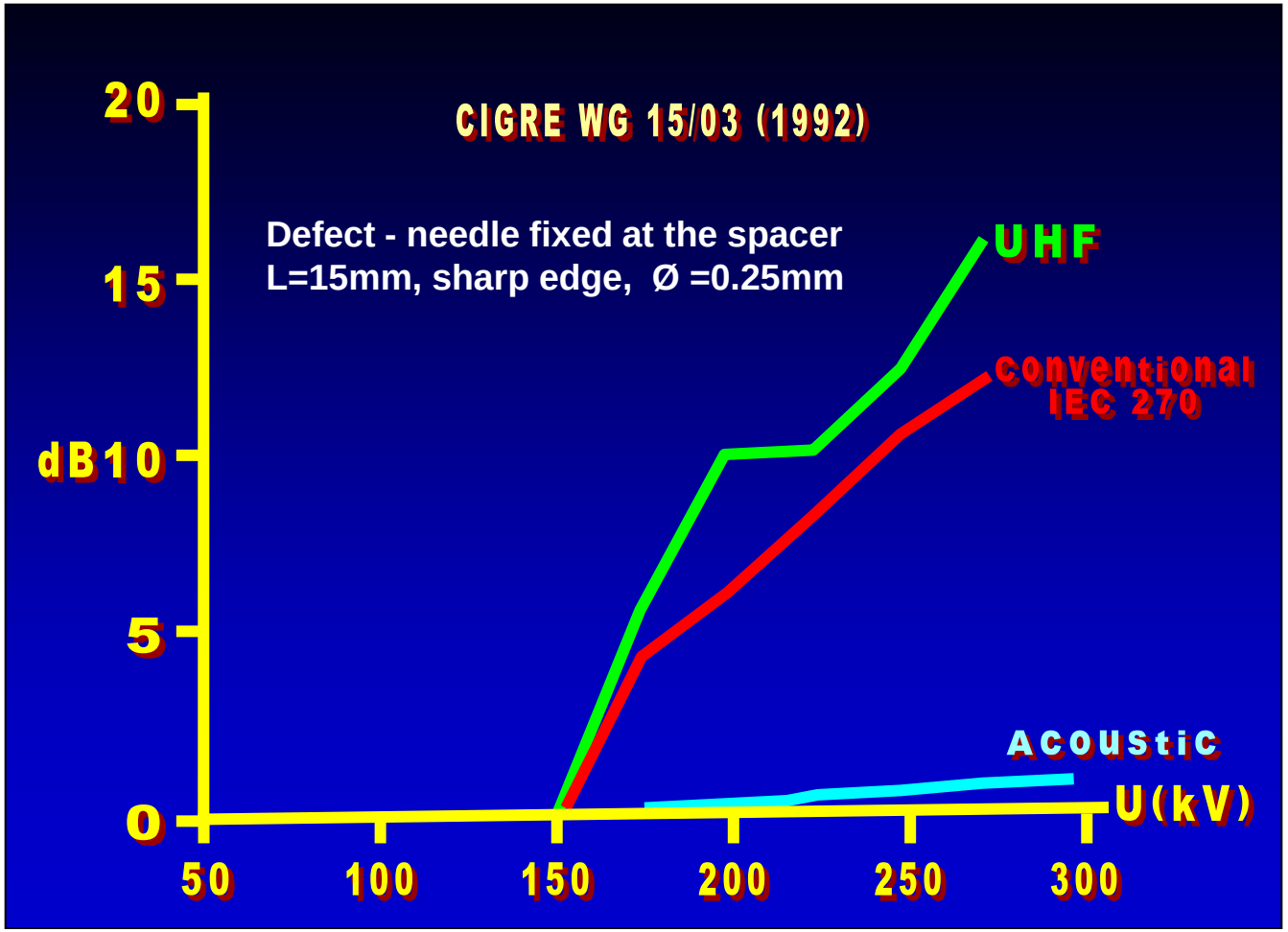
CIGRE Investigation (1992)



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Relative Merits:- UHF and Acoustic PD Systems

	UHF-System	Acoustic-System
Main purpose	☺ detection & 😐 localisation of PD sources	☹ detection & ☺ localisation of PD sources
Sensitivity	mobile particles (1-2mm), ☺☺ fixed particles (2-5mm) floating components voids in spacers	mobile particles, 😐 fixed particles, floating components ☹ voids in spacers
Measurement time / bay for spot checks	☺ 5-10 minutes, easy and fast	☹☹ min. 30 - 90minutes "one has to crawl on GIS"
Suitability for on-line continuous monitoring	☺☺ Reliable sensors, noise immune and large sensor spacing	☹☹ Unreliable sensors, noise issues and needs many sensors

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Relative Merits:- UHF and Acoustic PD Systems

	UHF-System	Acoustic-System
Typical system requirements	😐 built-in sensors, ☺ (or in some cases external spacer sensors)	☺ no built-in sensors required !
Noise reduction	☺☺ very effective,	☹ not possible, **additional** noise sources: wind, rain droplets, vibrations, air corona
Data storage	☺ easy and fast on PC	😐 only possible with AIA type instrument
Data analysis during and after measurement	☺ easy and fast, use of PD database for analysing and classifying data	😐 AIA system: possible to some extent

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What Makes a UHF PDM System so Effective:

- can detect all known types of PD in GIS, Transformers or rotating machines
- can record data in a way which allows the analysis of PD using expert system PD pattern interpretation by ANN and feature extraction
- can instantly warn of active PD (no time delay)
- gives indication of the type of PD and therefore helps in determining the risk of failure

What Makes a UHF PDM System so Effective:

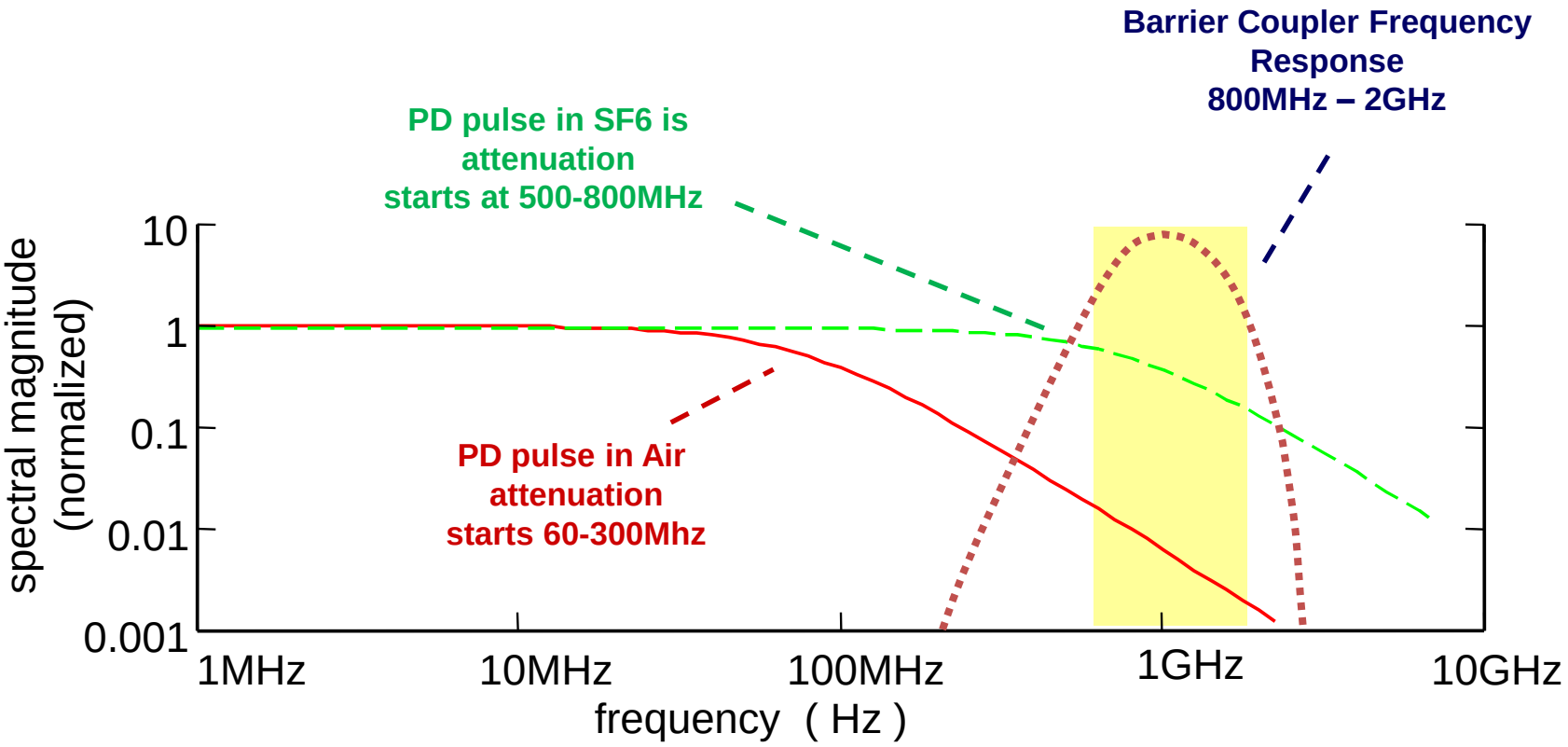
- suitable for periodic and continuous, on-line monitoring in-service
- applicable to all system voltages
- only IEC approved technique for use during HV commissioning tests (of GIS)
- Also suitable for other metal enclosed electrical plant such as, dead tank CBs, cable end boxes and switch-panels

What Makes a UHF PDM System so Effective:

- The UHF method can reject external “air corona” produced noise, as this occurs at lower frequencies (HF and VHF)

- This is because the “fast” PD pulses in SF_6 or Oil produce strong signals at frequencies much higher than normal “air corona”

Physics of PD Attenuation



Best SNR with still sufficient sensitivity 1GHz±300MHz

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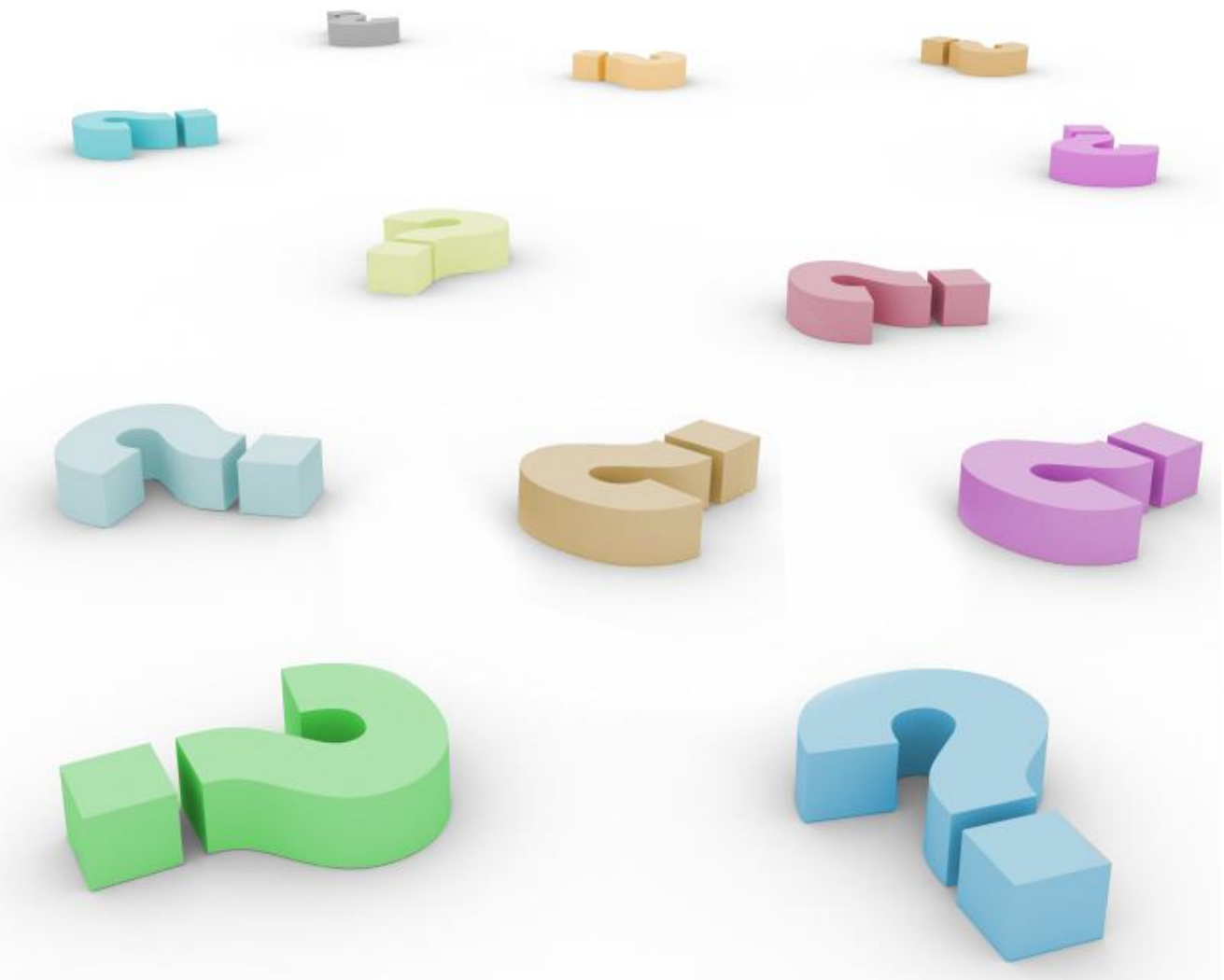
Questions ?



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Continuous monitoring

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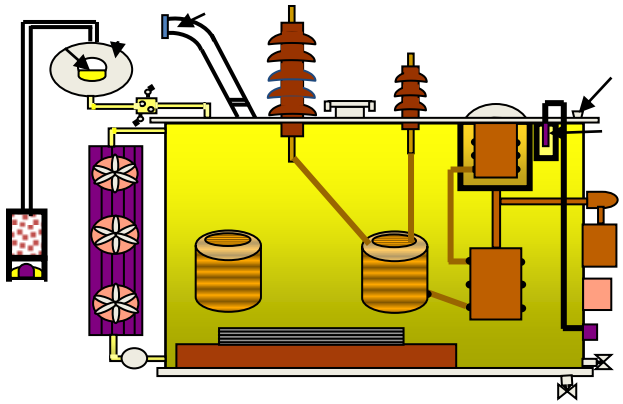
Periodic PD monitoring For Transformers (Portable Unit)



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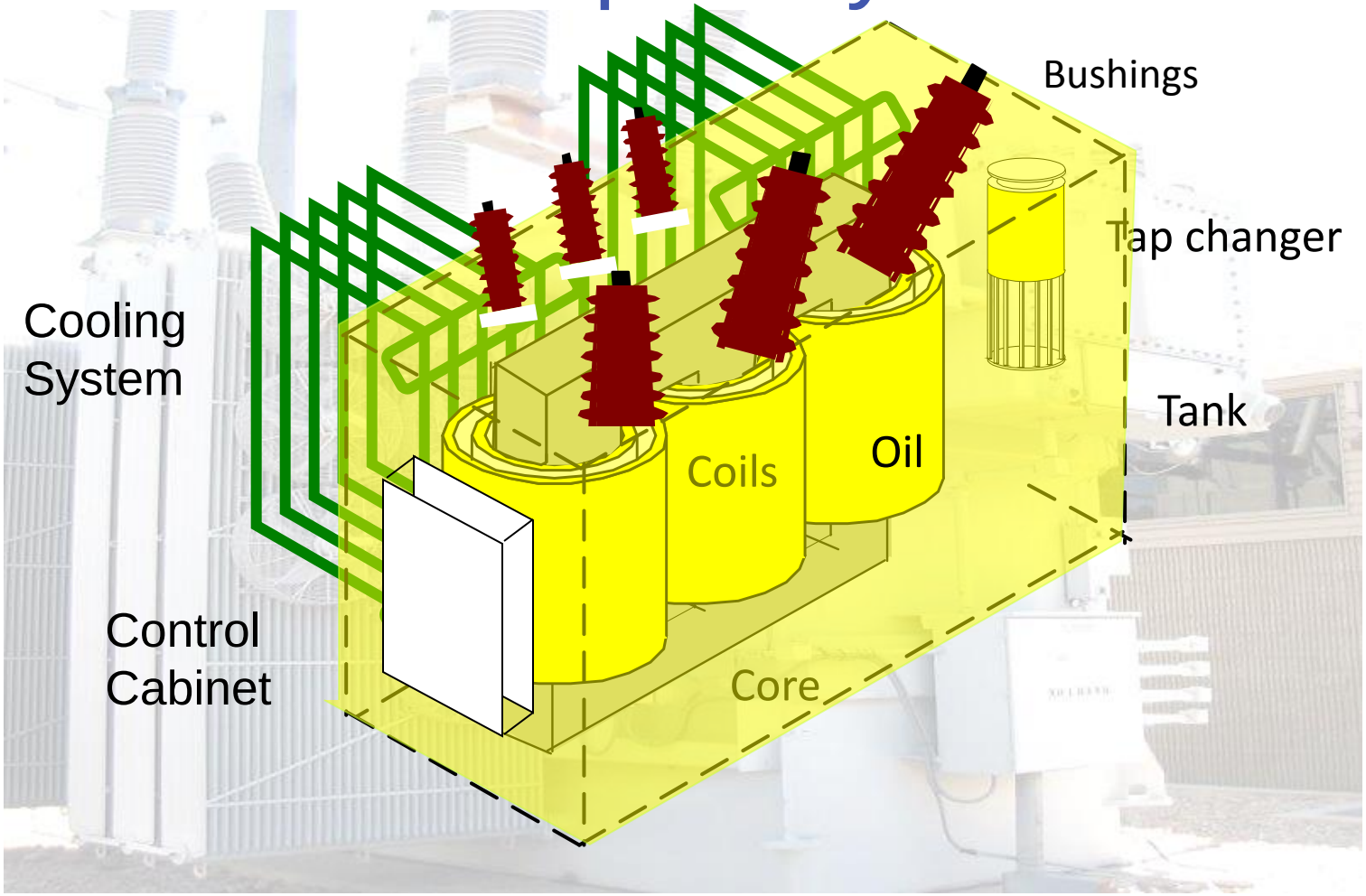
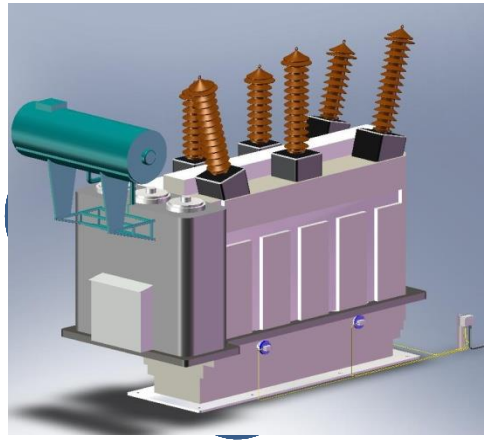
The Transformer
A complex system



Transformer Tests

AC Hi-Pot

Partial Discharge



TTR

C & DF PF

SFRA

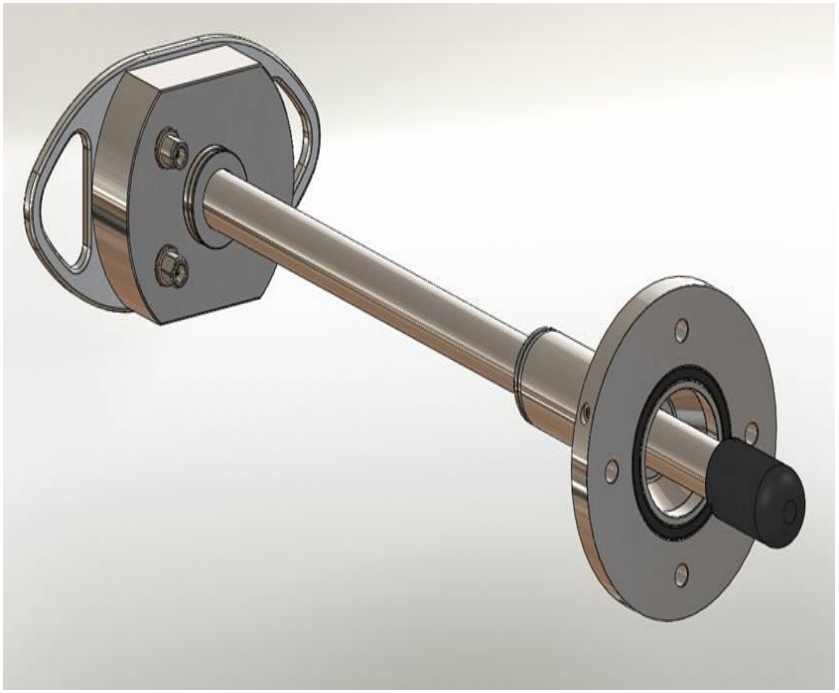
DC Winding

Oil

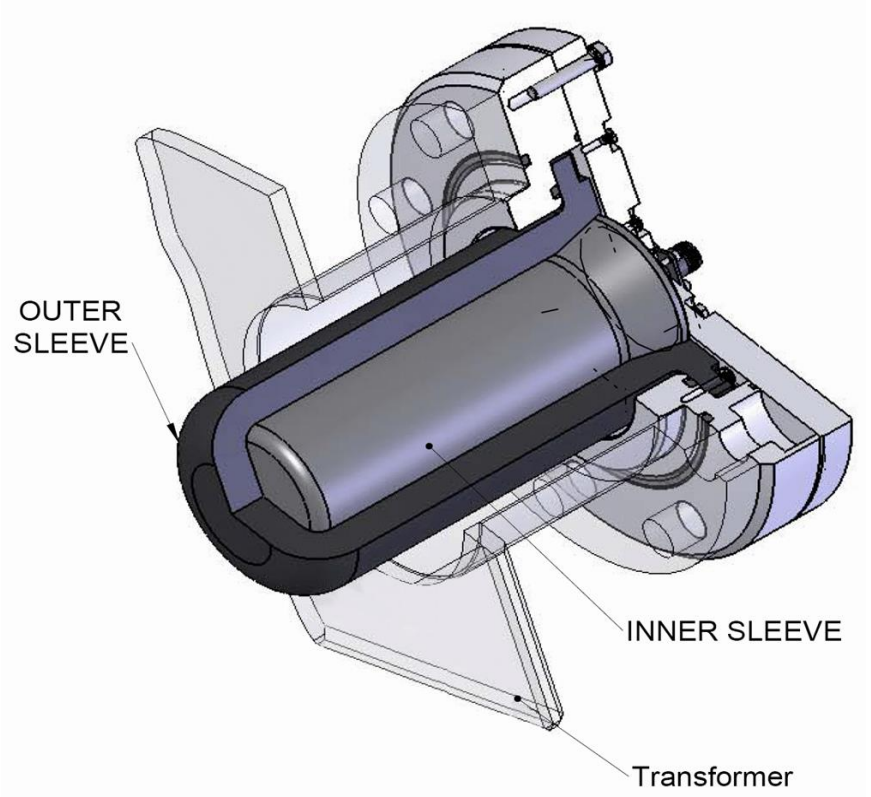
Insulation Resistance

PD Sensors for Transformers

Oil Drain Valve Probe



Window coupler (patented)



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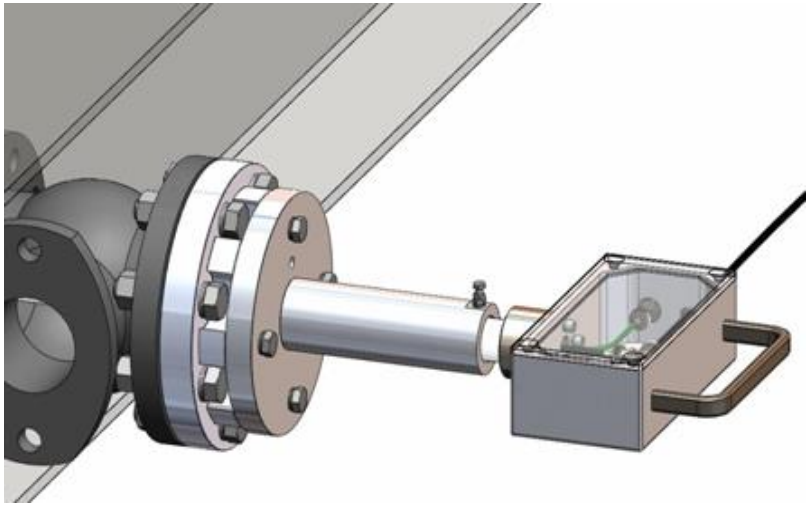
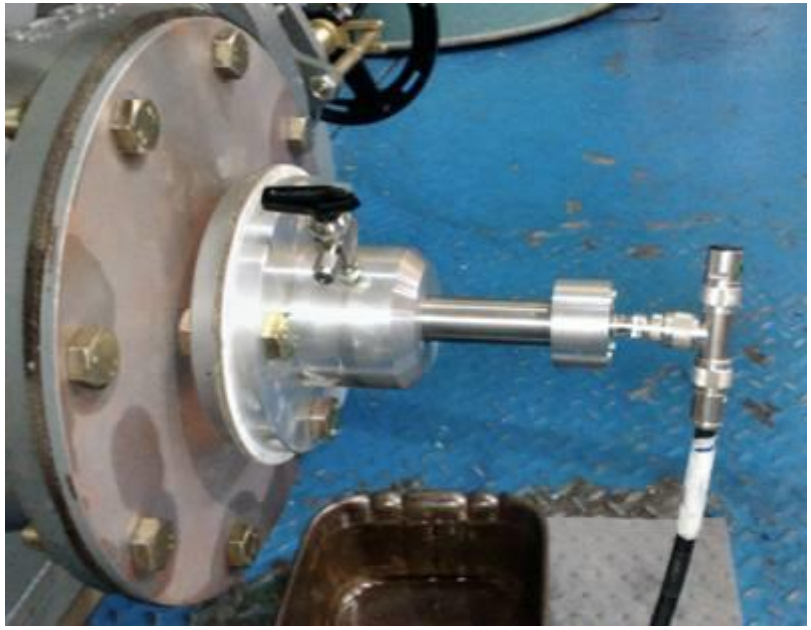
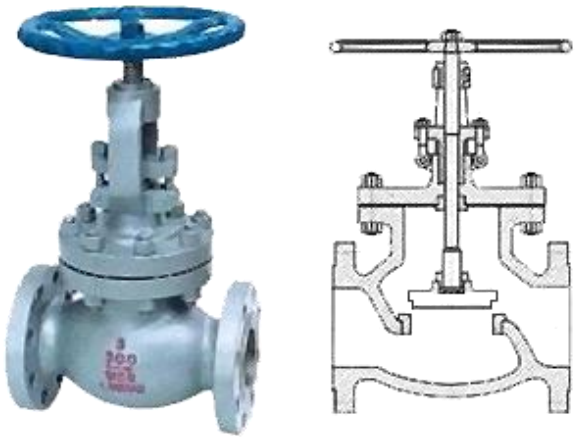
Oil Drain Valve Probe

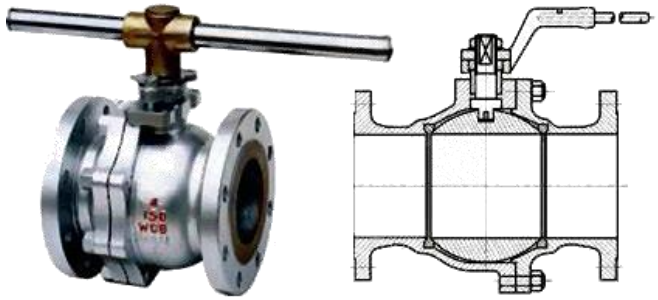




Suitable Types of Valves



✗ Globe/Stop Valve



✓ Ball Valve

PD in a transformer can be monitored using UHF sensors inserted into the oil drain/filter valves provided that they are the correct type.

✓ Gate Valve

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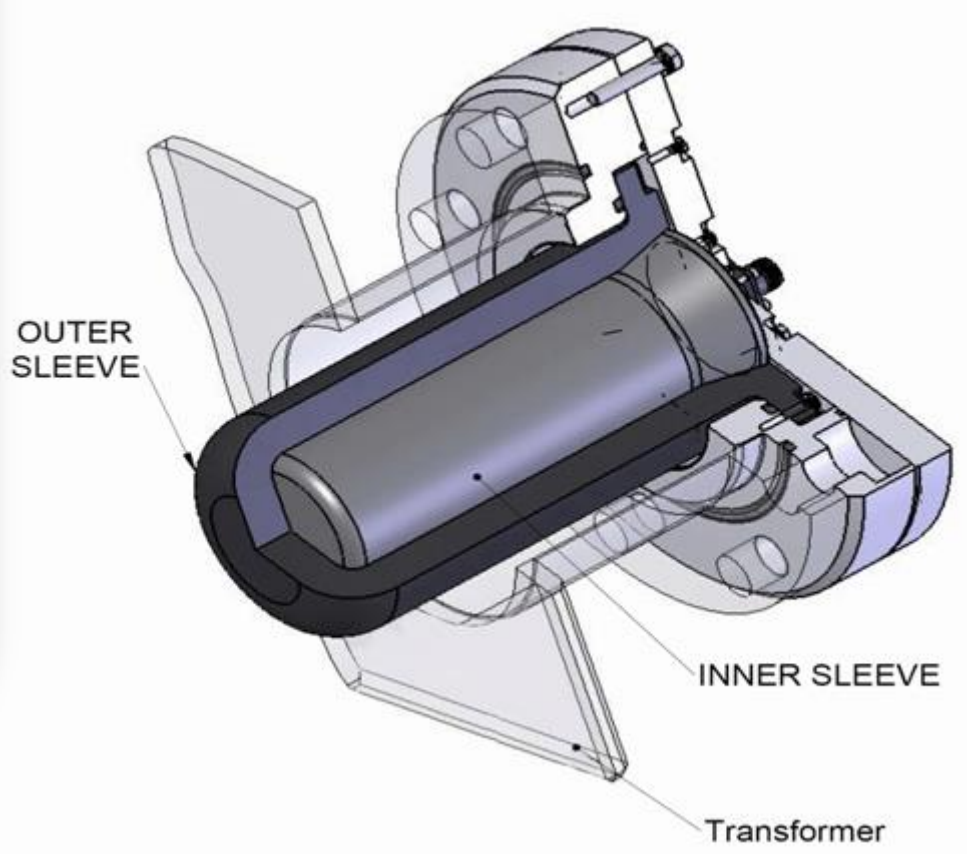
Window Coupler

Window sensor

Window sensor (patented)



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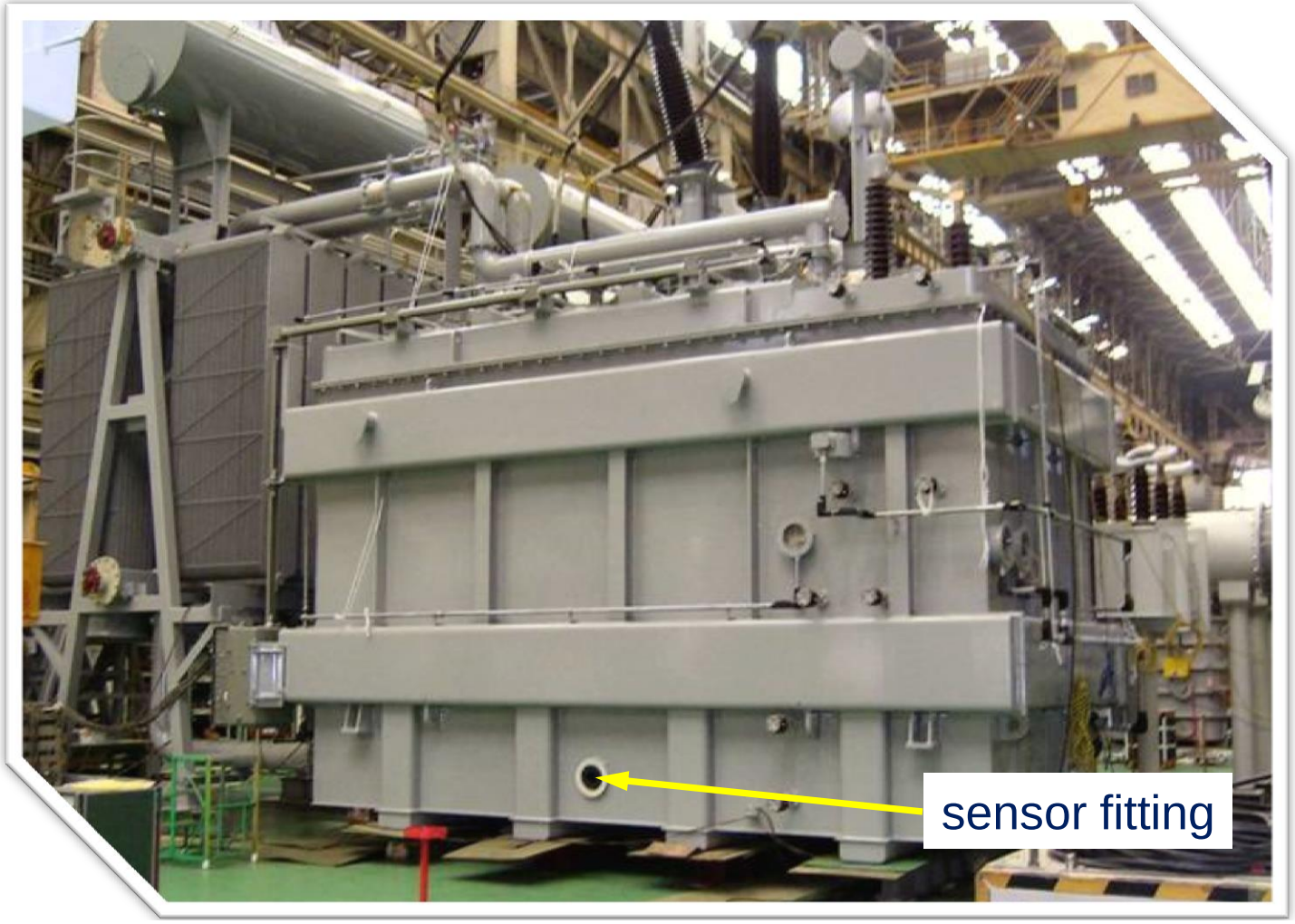
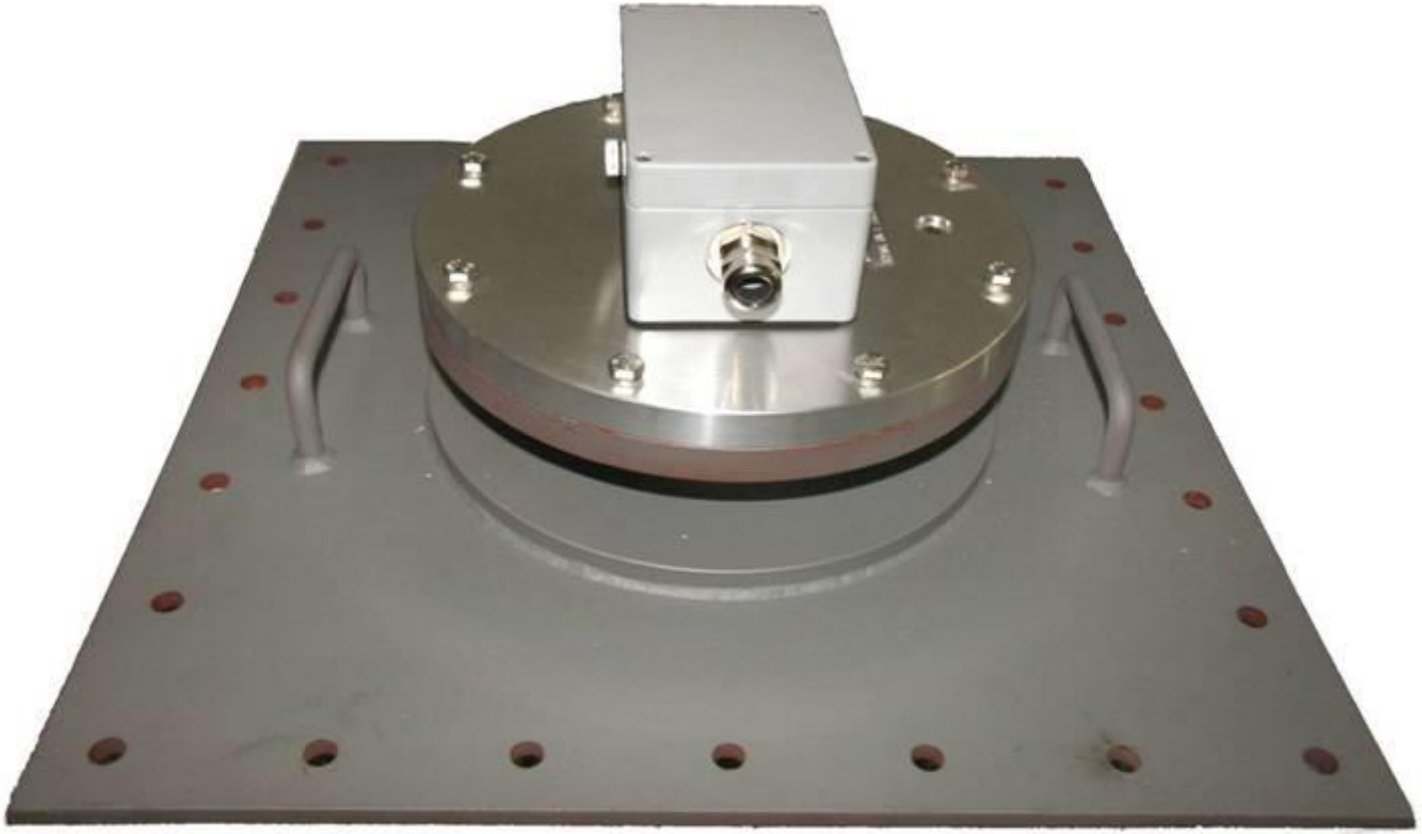
Transformer with UHF Sensors



PD Sensors fitted to a new build 400kV Phase Shift Transformer

Transformer UHF Sensor - Retrofit to hatch cover



PD sensor fitted to a manhole hatch cover

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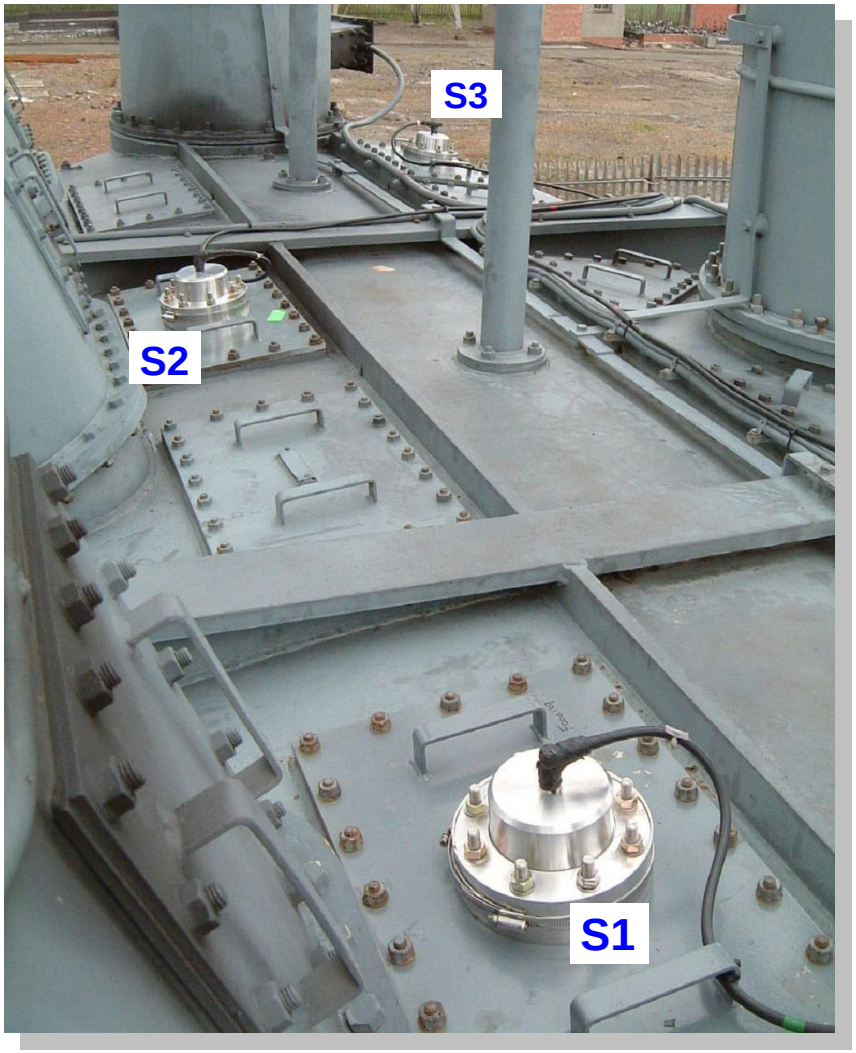
Transformer with Retrofit hatch cover



- Replacement hatch covers were prepared before the installation
- Sensors fitted on top of tank to the replacement hatch covers
- Oil was only drained to a few cm below the hatch level
- Outage time was kept to a minimum

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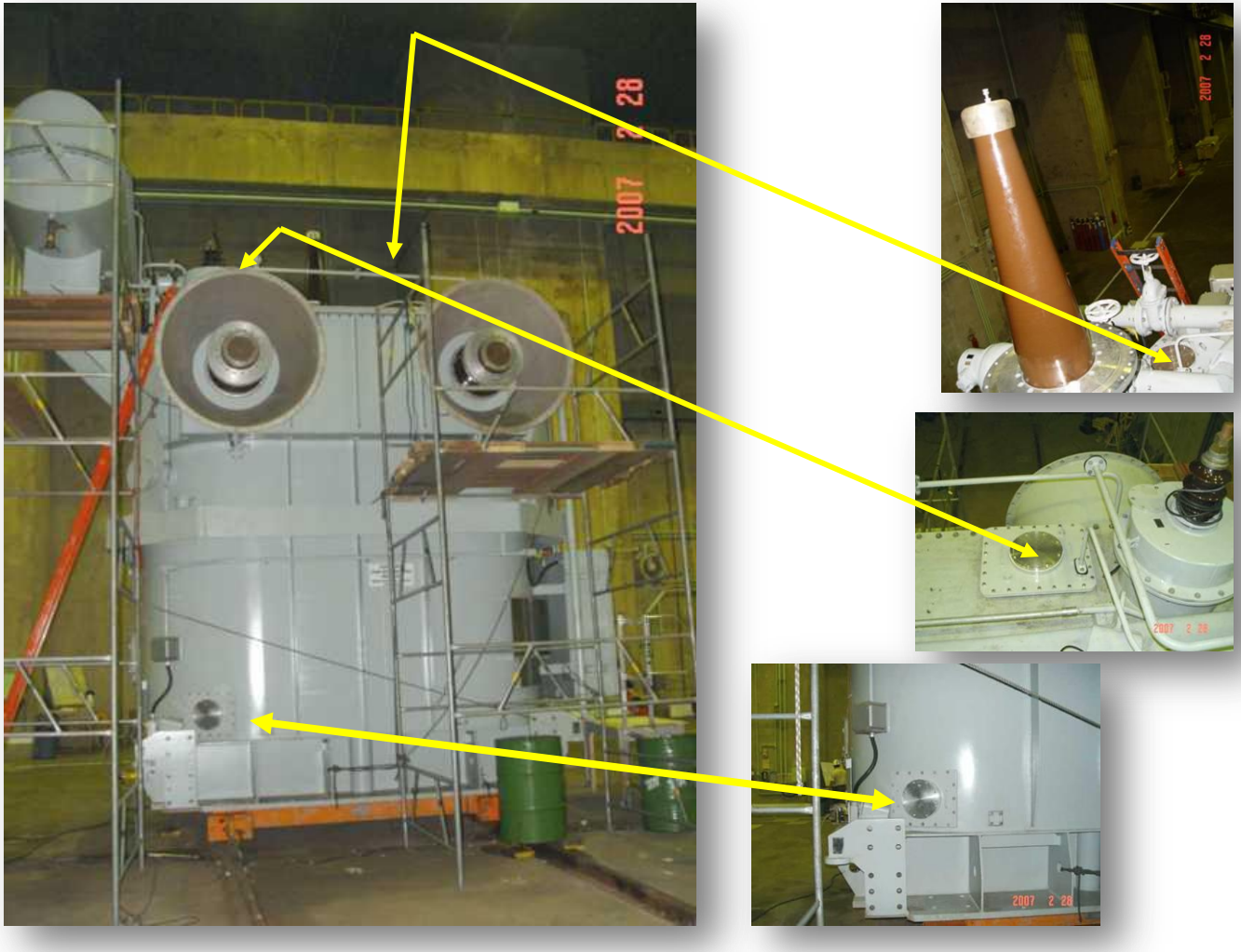
PD couplers retrofitted to a repaired unit transformer



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UHF Sensors Termination Box

Sensors fitted to tank and connected to a termination box for periodic monitoring

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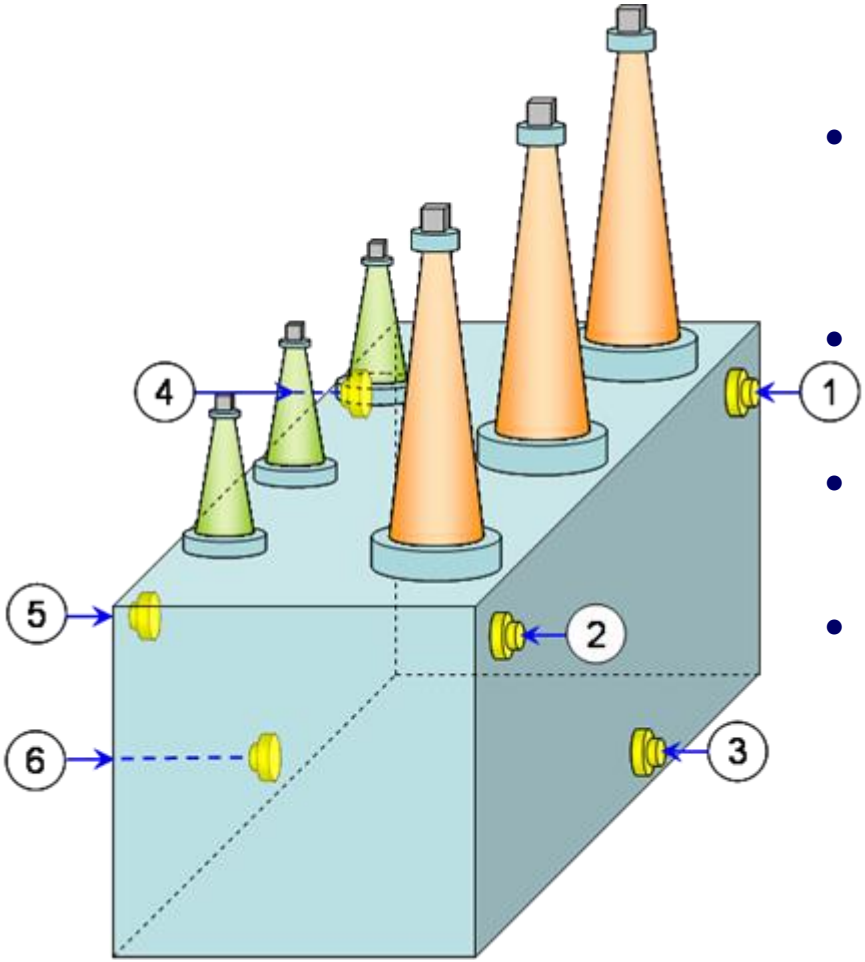
Placement of UHF Sensors on Transformers



- **Sensors are to be fitted with maximum possible spacing between them to allow better triangulation of signal**
- **Standard sensors must not intrude into high field areas – special sensors are available for such areas**
- **Sensors near top of tank are more sensitive to defects in bushing connection area**
- **Lower sensors can be installed using drain valves (this does not need oil to be drained)**
- **Number of sensors depends on size of transformer (minimum of 3 needed for location, 4 to 6 preferred depending on complexity of internal parts, separate tap changers etc.)**

Portable PDM System Overview

- The DMS Portable UHF Monitor **detects and records** the UHF signals generated by partial discharges in a GIS

- The Portable UHF Monitor consists of a base unit and a detachable laptop computer which are fitted into an aluminium travelling case and require only an external mains supply to be ready for use. The Monitor can be left connected and unattended, where it will record and store data from up to three couplers.

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Portable PDM System Overview

Practical Uses

- The Monitor is often used to undertake **surveys in substations** to provide early warning of developing faults, enabling them to be corrected before complete breakdown occurs.
- The Monitor can be used during the HV **commissioning** on new GIS and the **in-service operation** of the substation.
- It is also used as the next tool for **localising PD** as a result of any PD indications given by a SmartHub Gen III system.
- Following detection using the DMS Portable UHF Monitor, the UHF technique allows a defect to be further located by time of flight methods using a suitable oscilloscope.

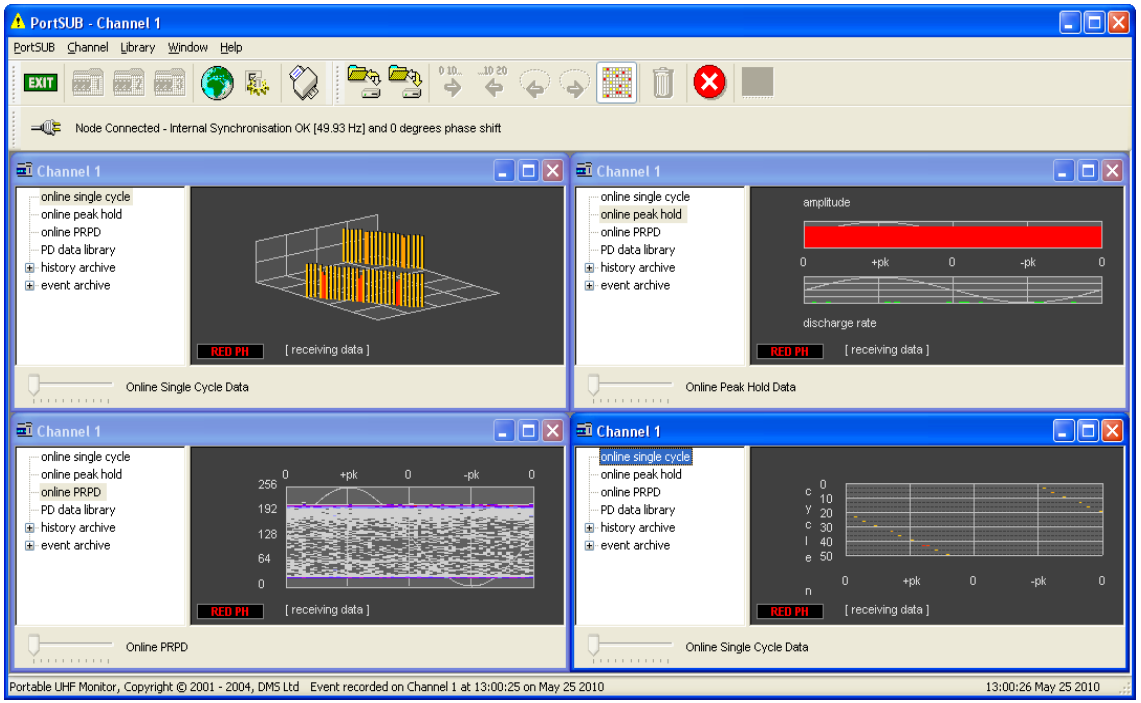
Portable PDM System

Accessories

- UHF Cable 3 x 10m for connection to couplers.
- 3 Phase 20dB Amplifier – to amplify PD signal for better analysis
- UHF Filters – To help reduce external noise masking PD signal
- DMS Overvoltage Protectors – To protect the system from transient overvoltages
- DMS HV Injection Unit – For checking coupler continuity / sensitivity

PDM System Overview
Software

PortSUB



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Portable PDM System Overview

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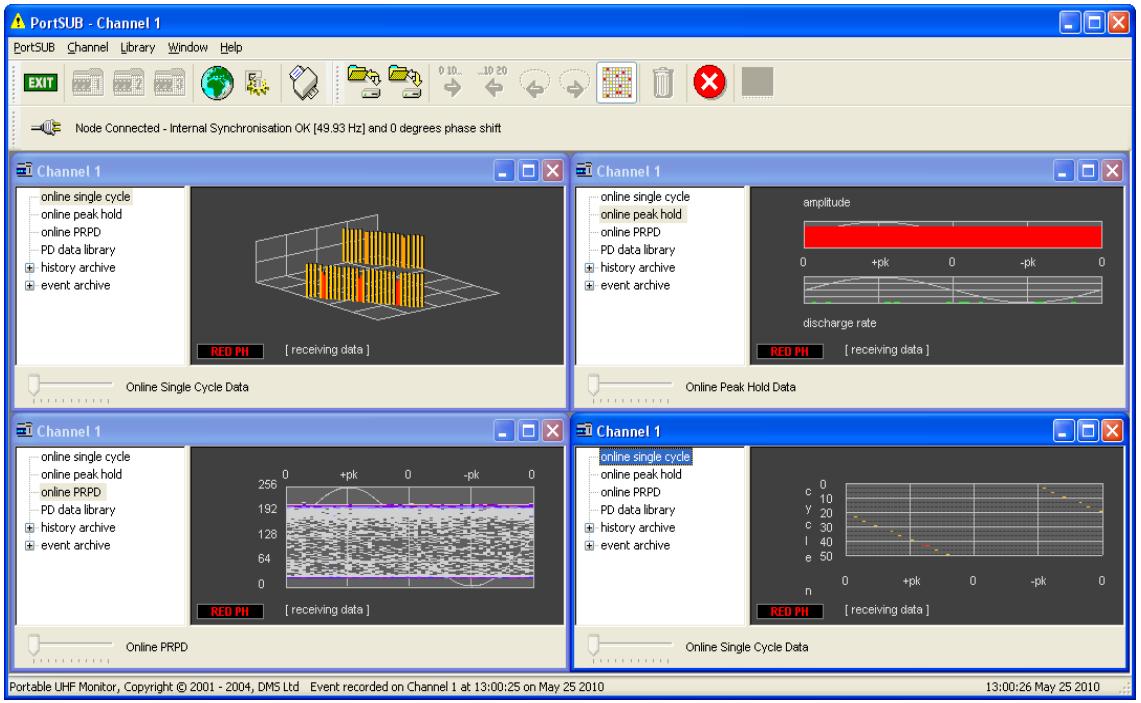
Portable PDM System Overview
Software

- Application software used on the Portable system is called PortSub.
- Collects and displays online data for instant measurements.
- Records and Stores data for multiple substations, and locations.
- Displays single cycle, peak hold, prpd, and history data in same format as Smartsub software.
- Data is analysed by a built in expert analysis module to give type of PD with a statistical probability
- Data can be easily transferred to other PortSub software installations for remote viewing

PDM System Overview
Software

PortSUB



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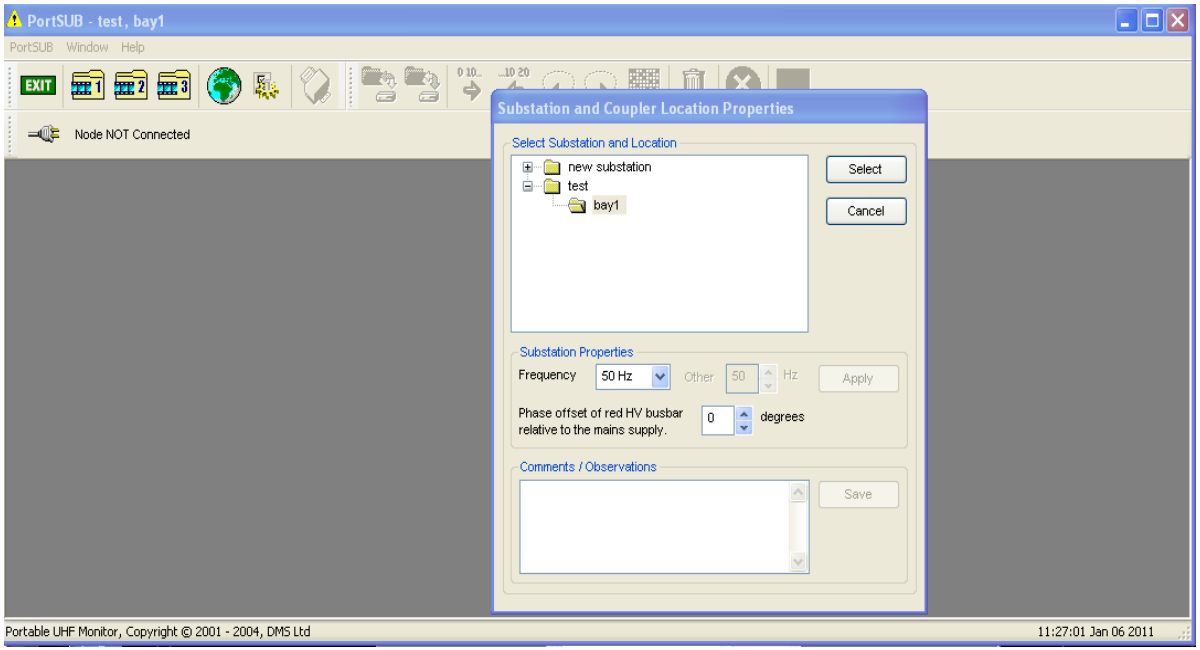
PDM System Overview
Software

PortSUB Substation Properties



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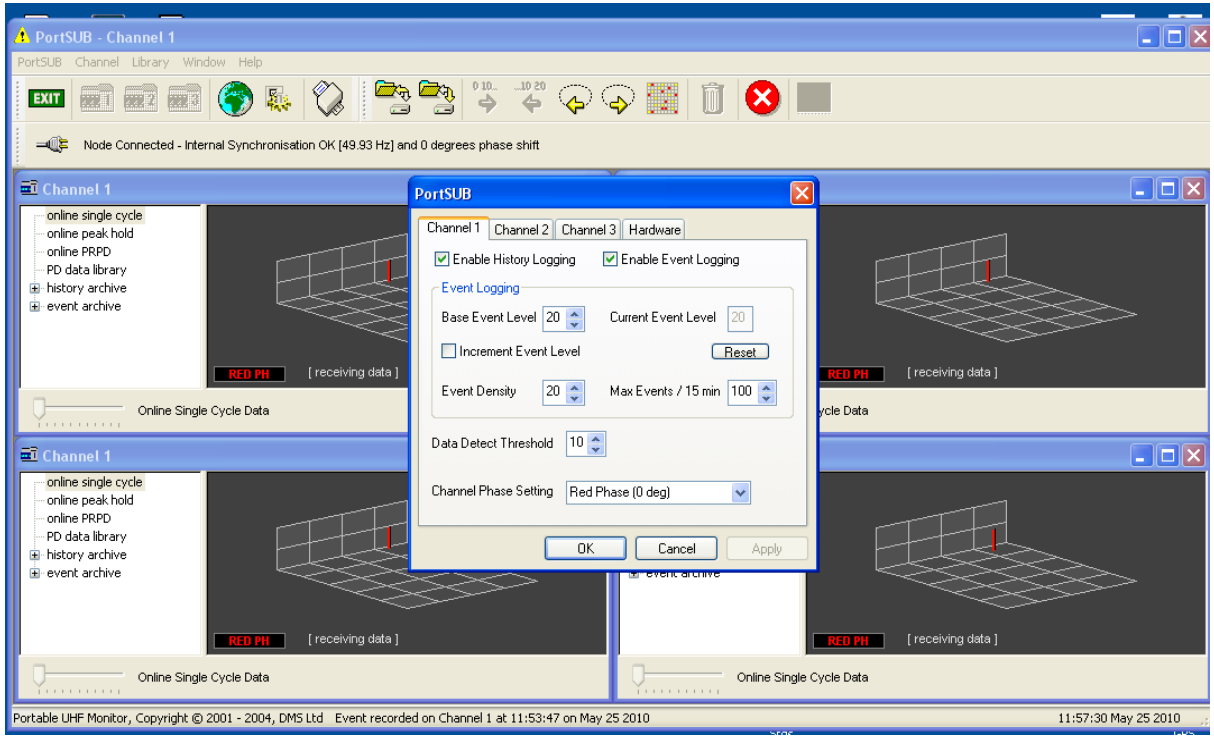
PDM System Overview
Software

PortSUB System Properties



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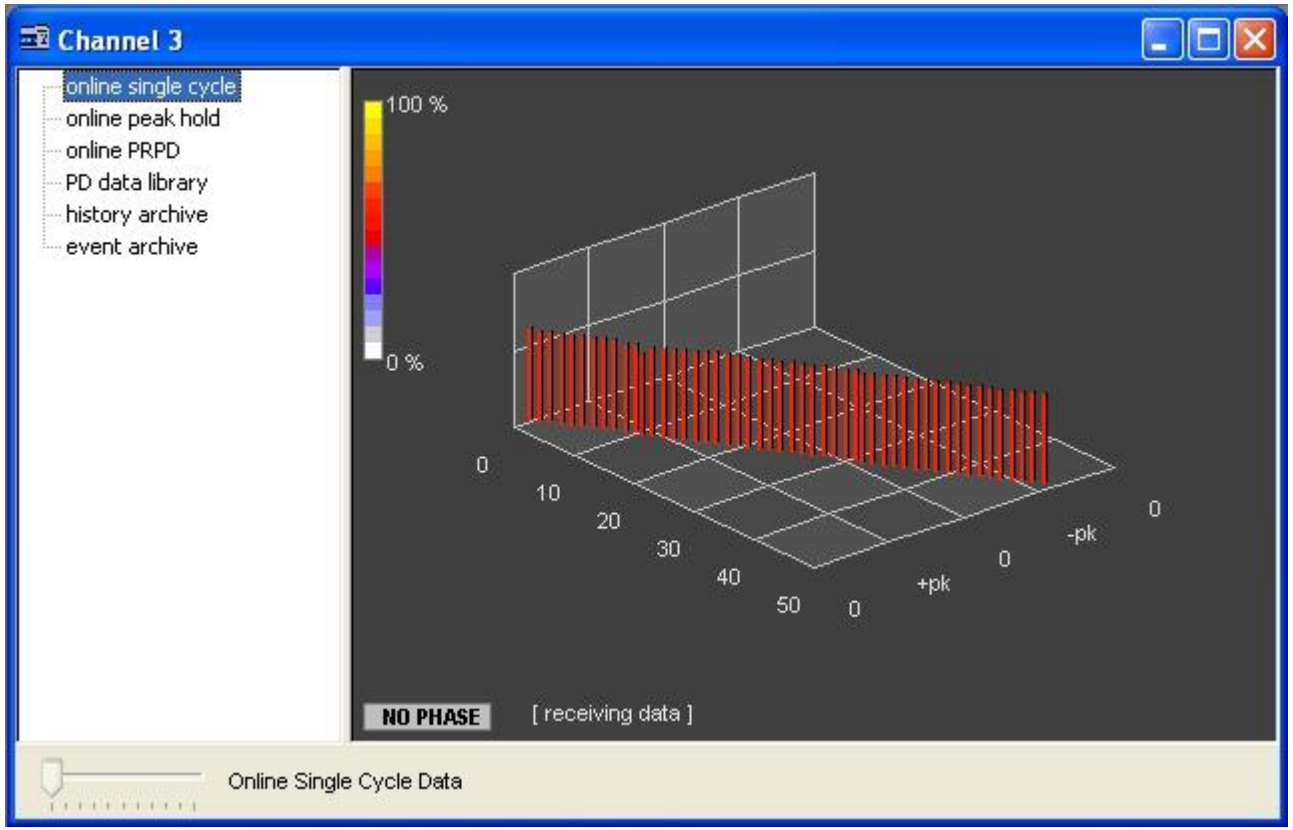
Single cycle display



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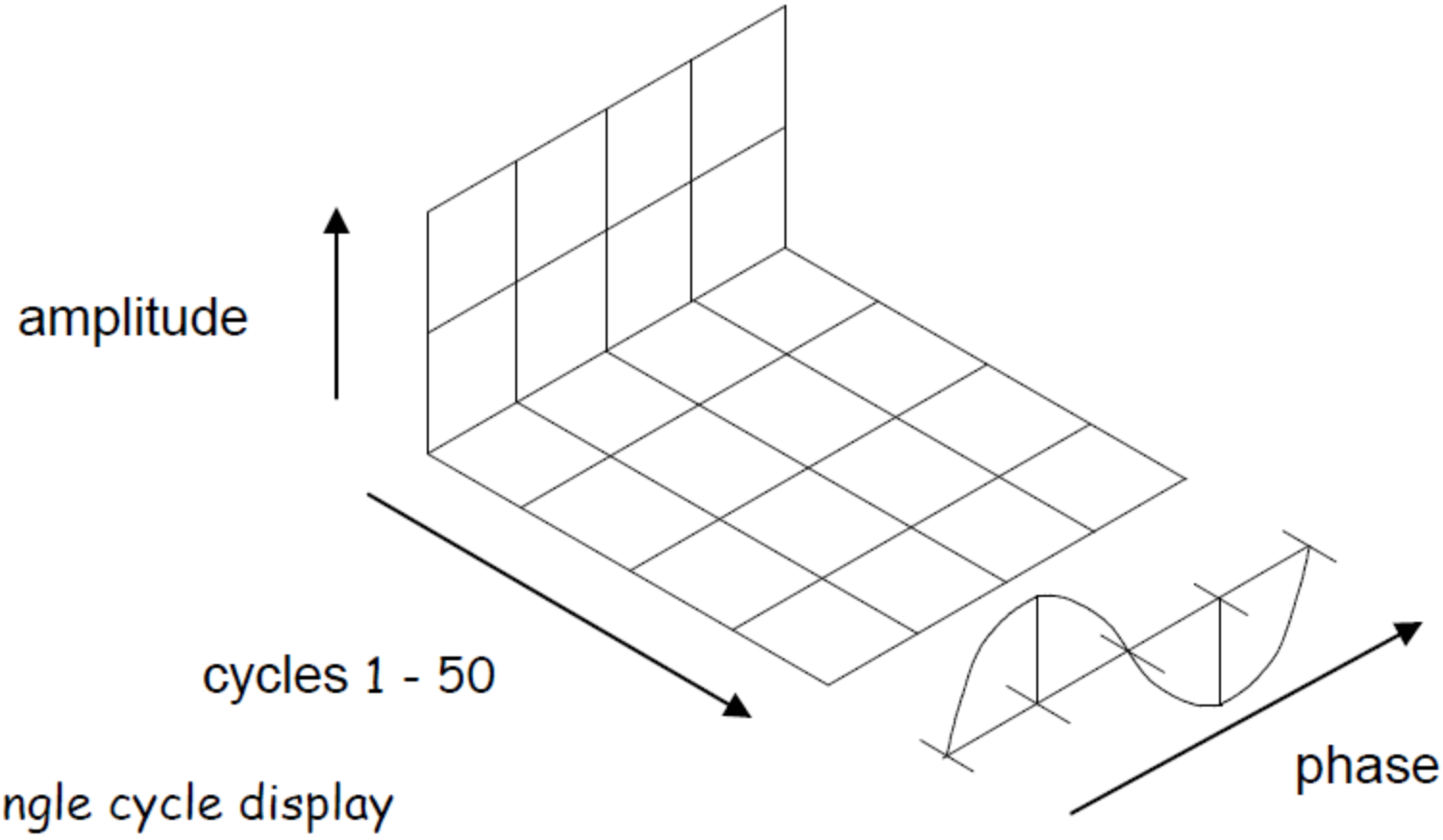
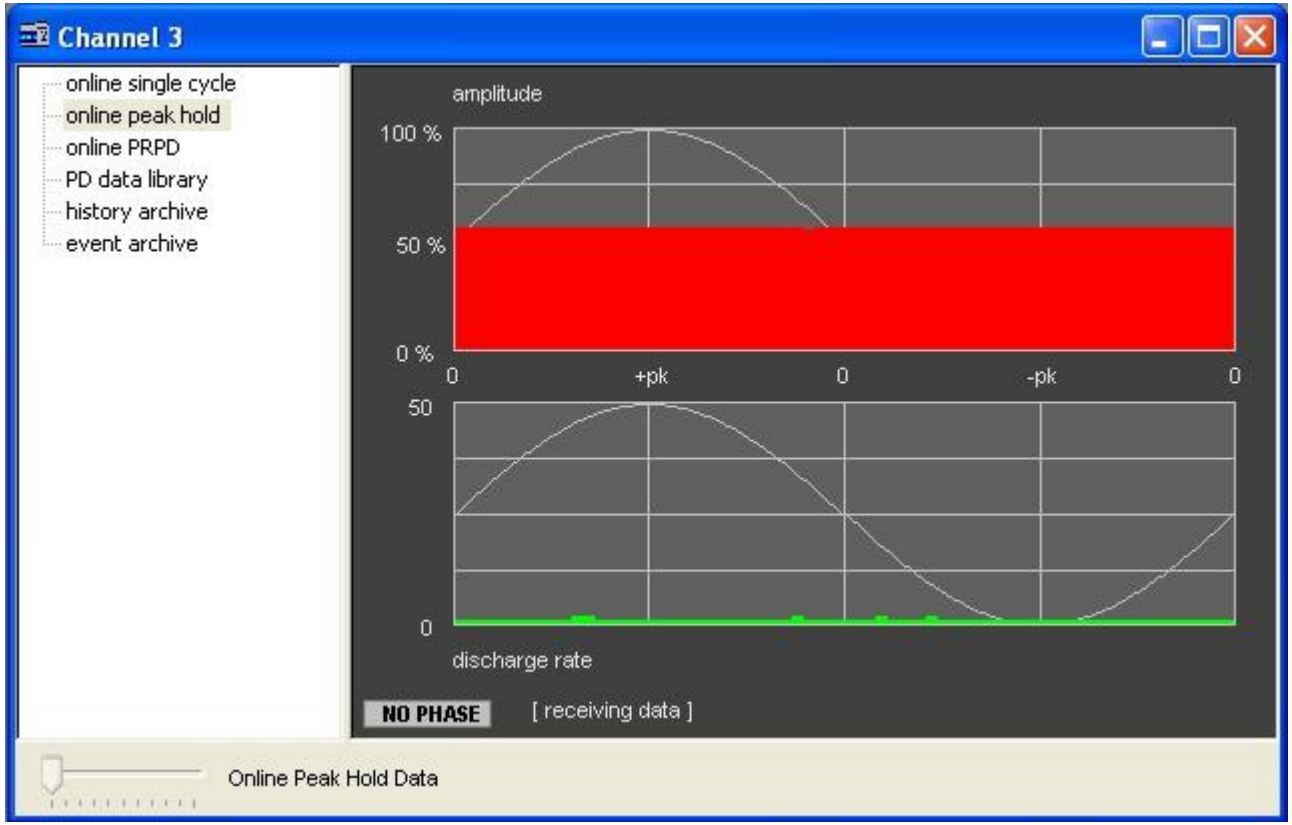
Single cycle display

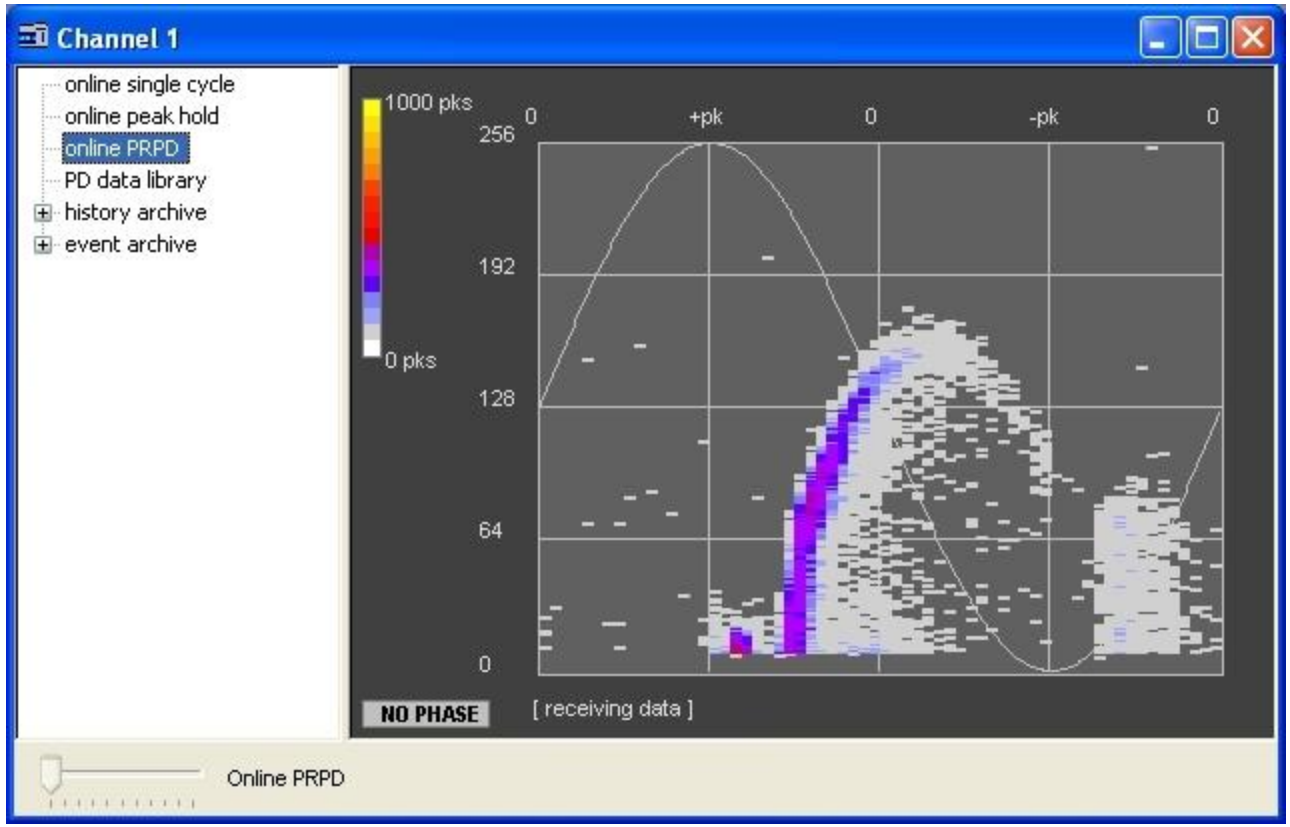


Single cycle display

Peak hold display



PRPD display



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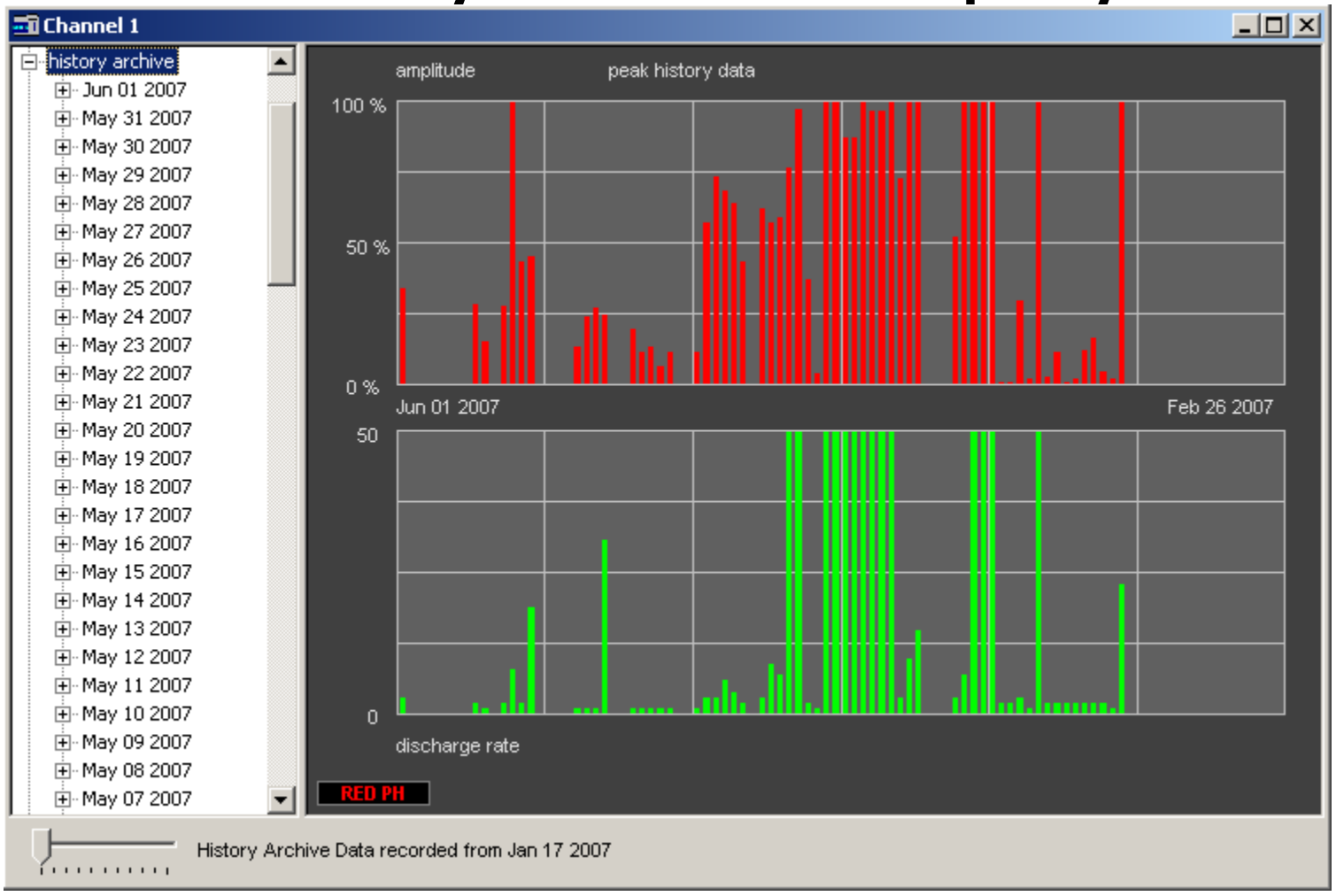
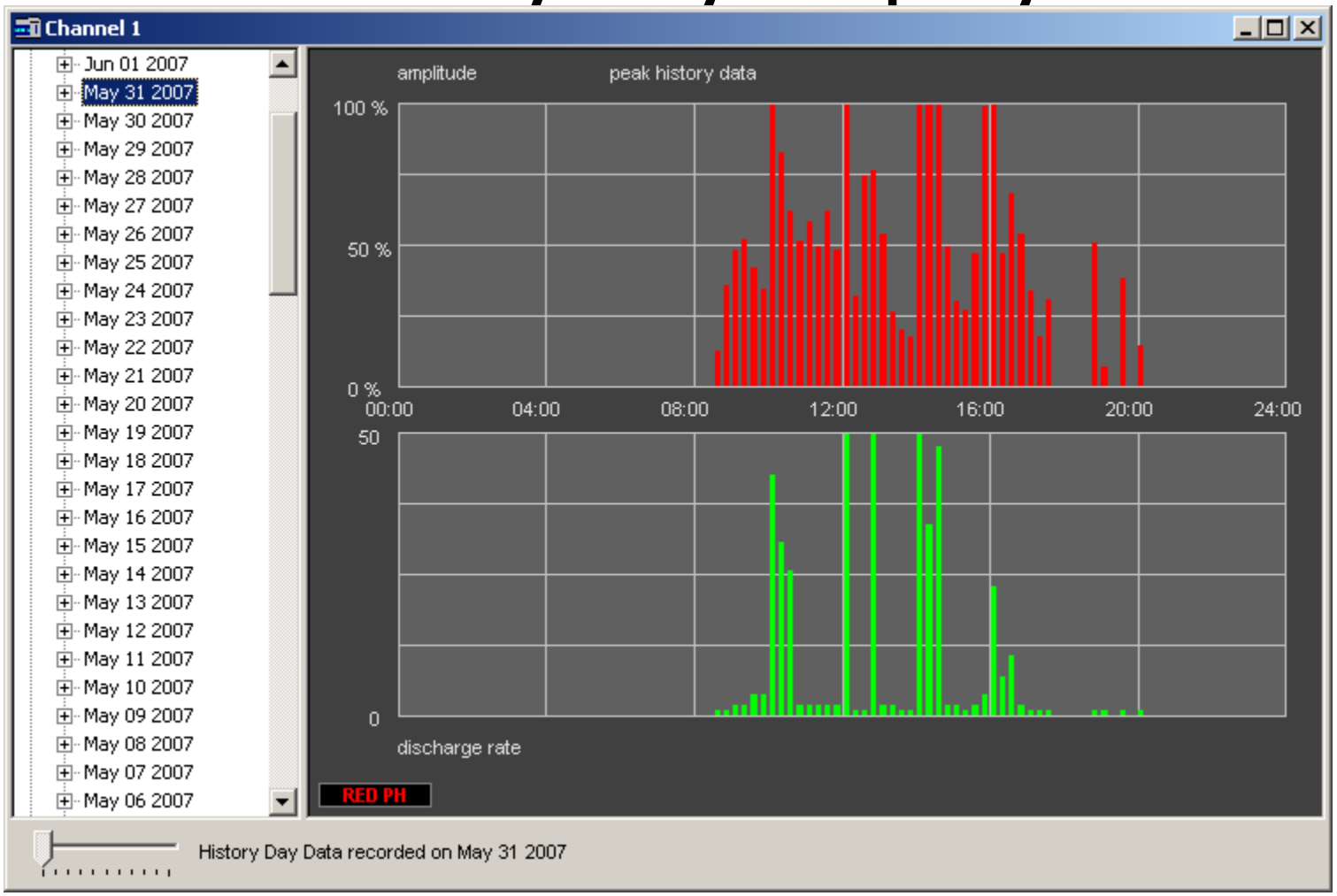
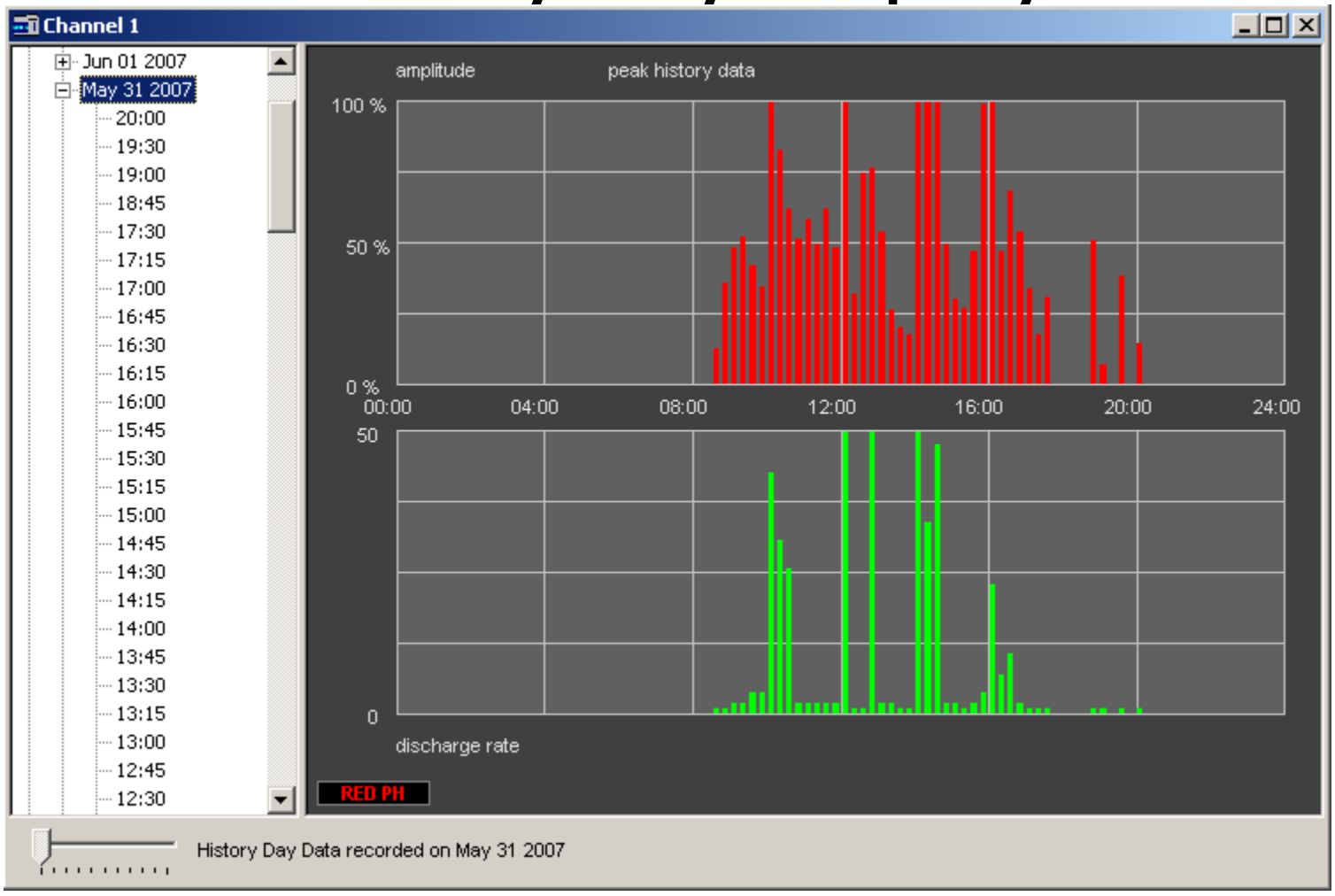
History archive display



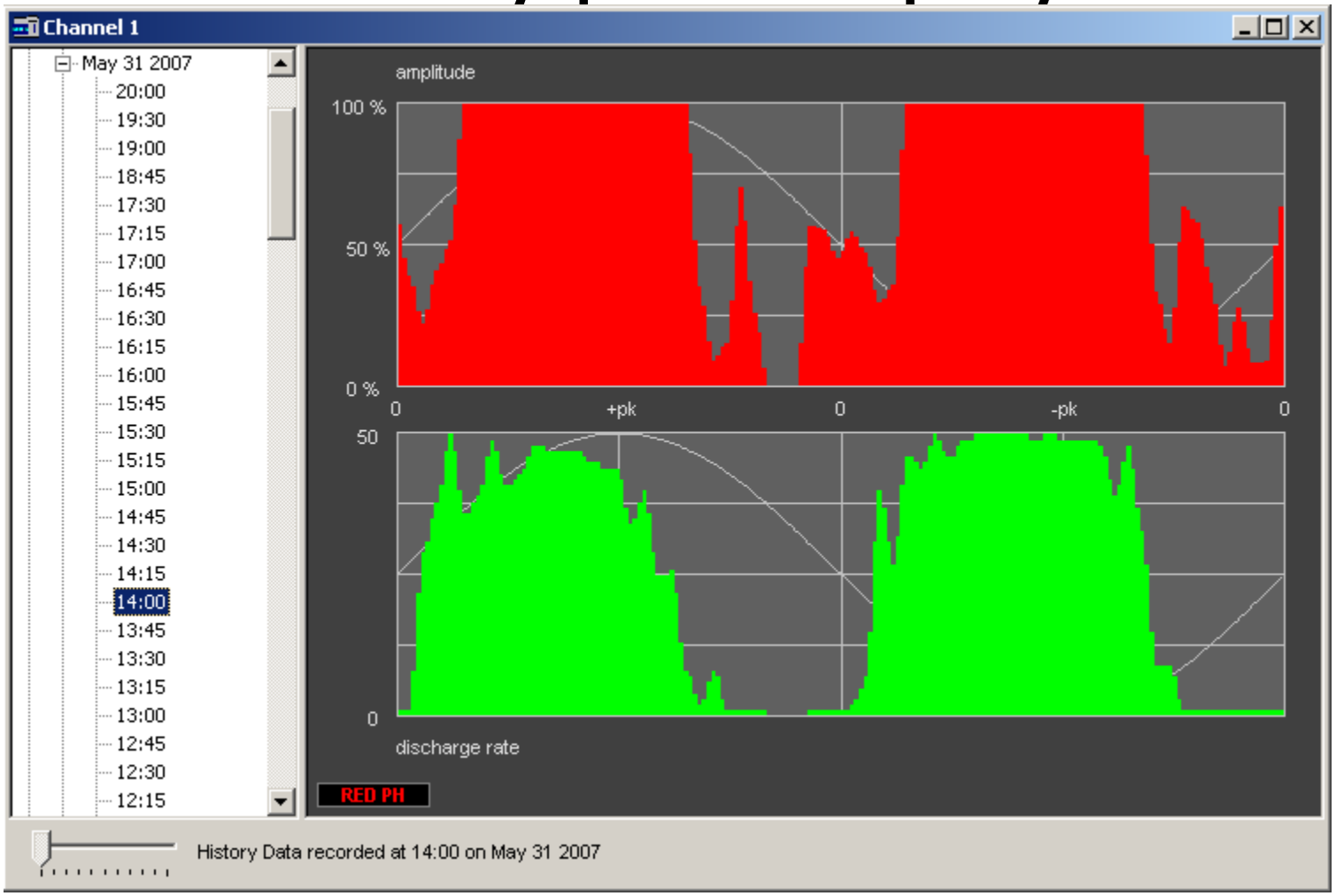
History day display



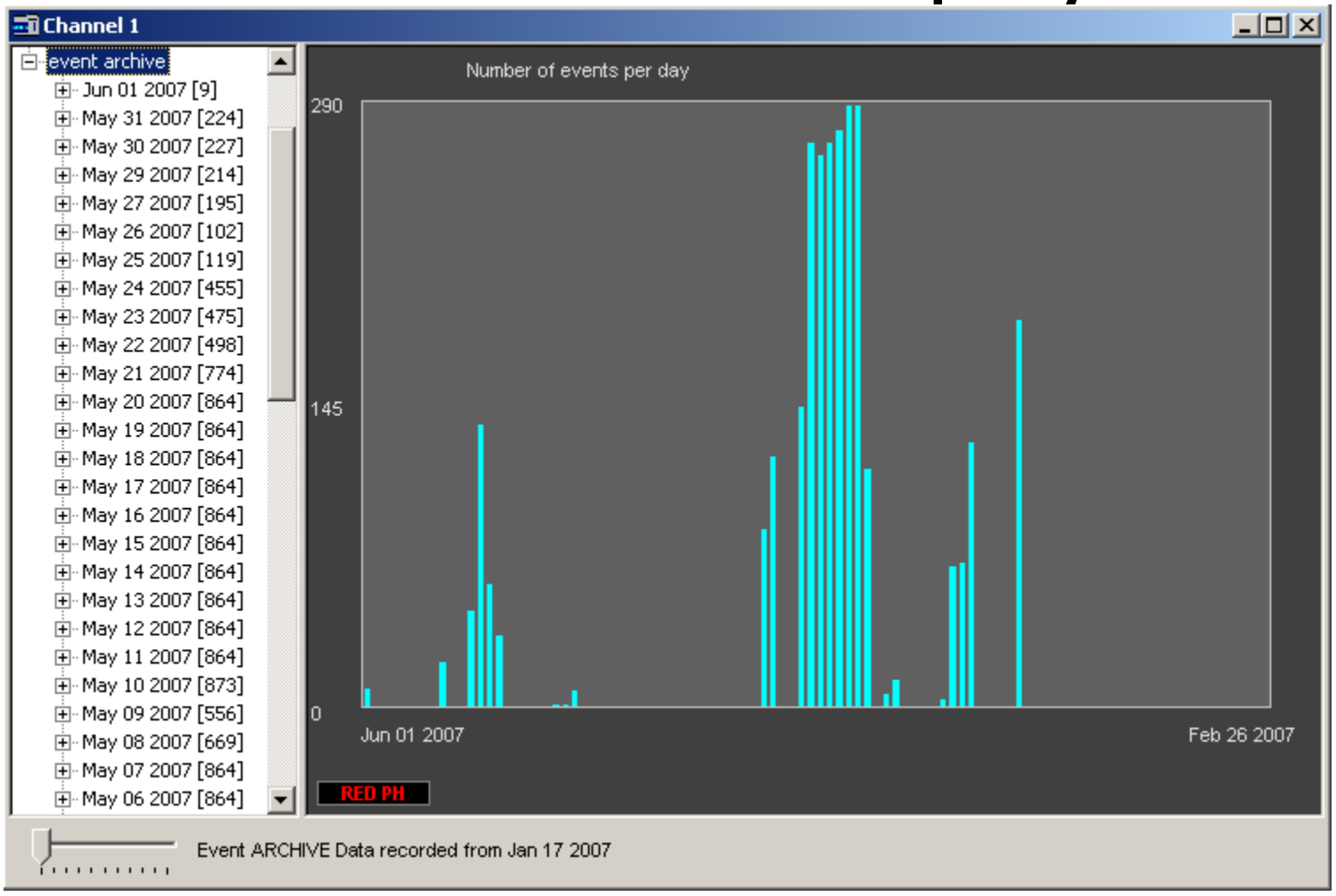
History day display



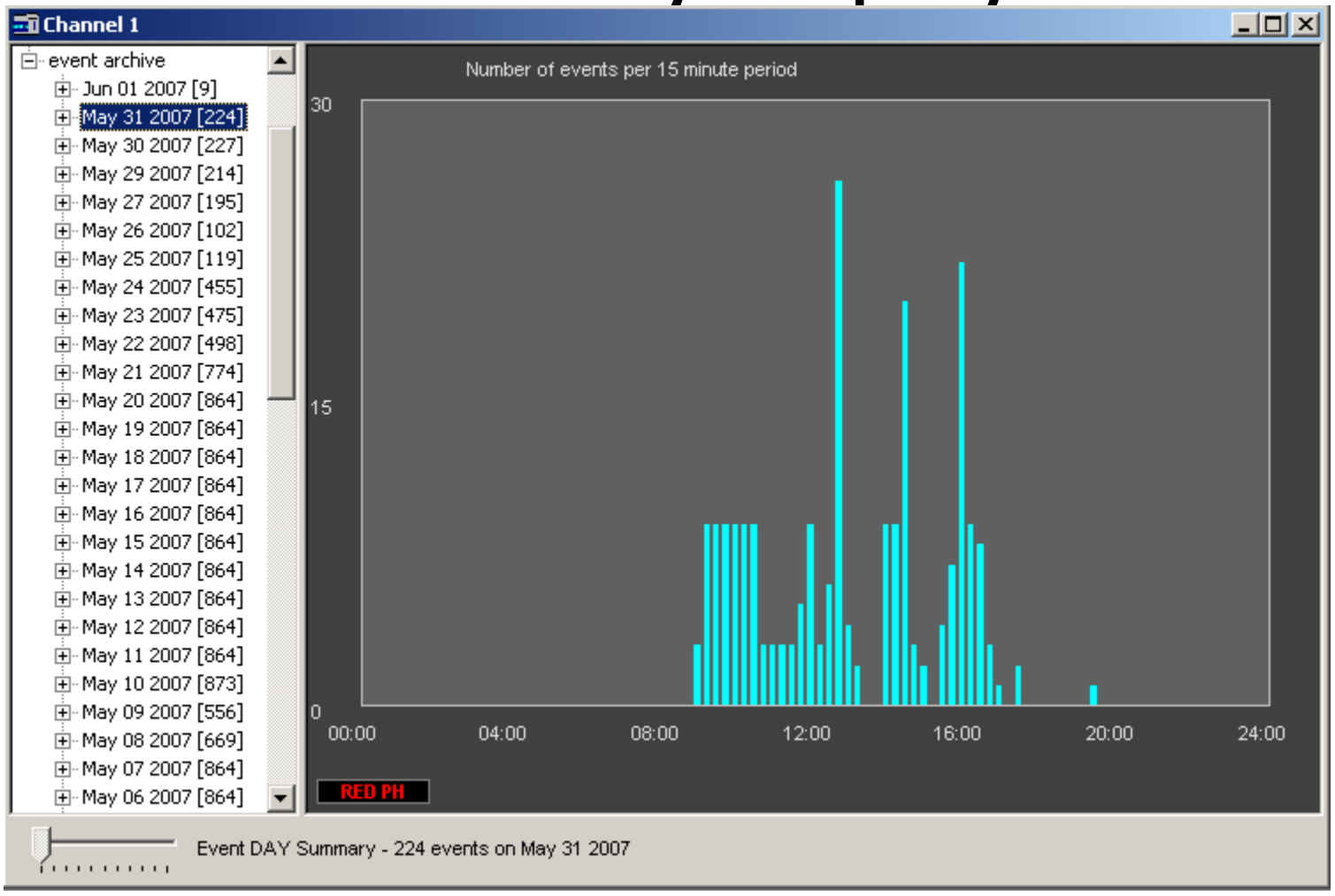
History pow display



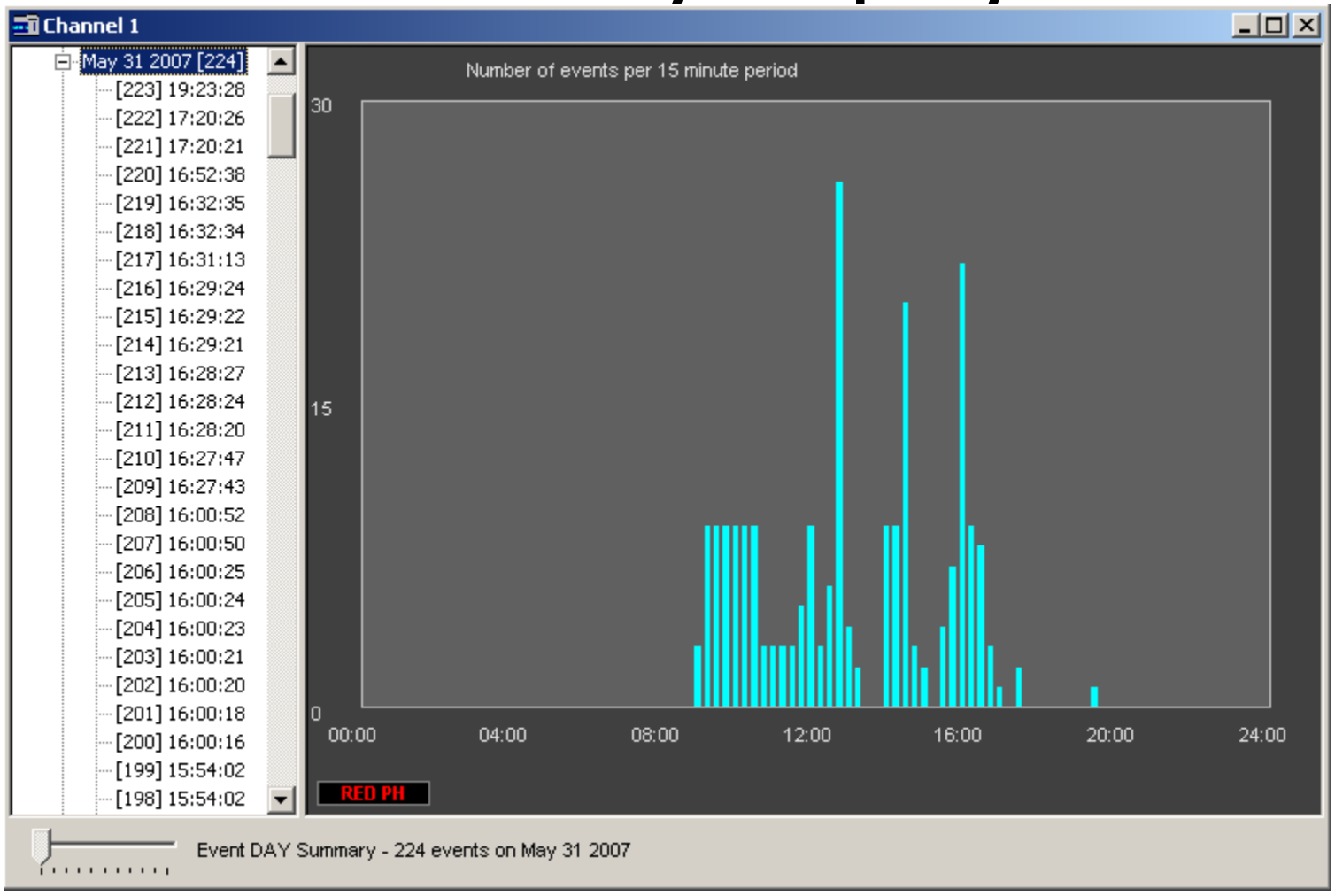
Event archive display



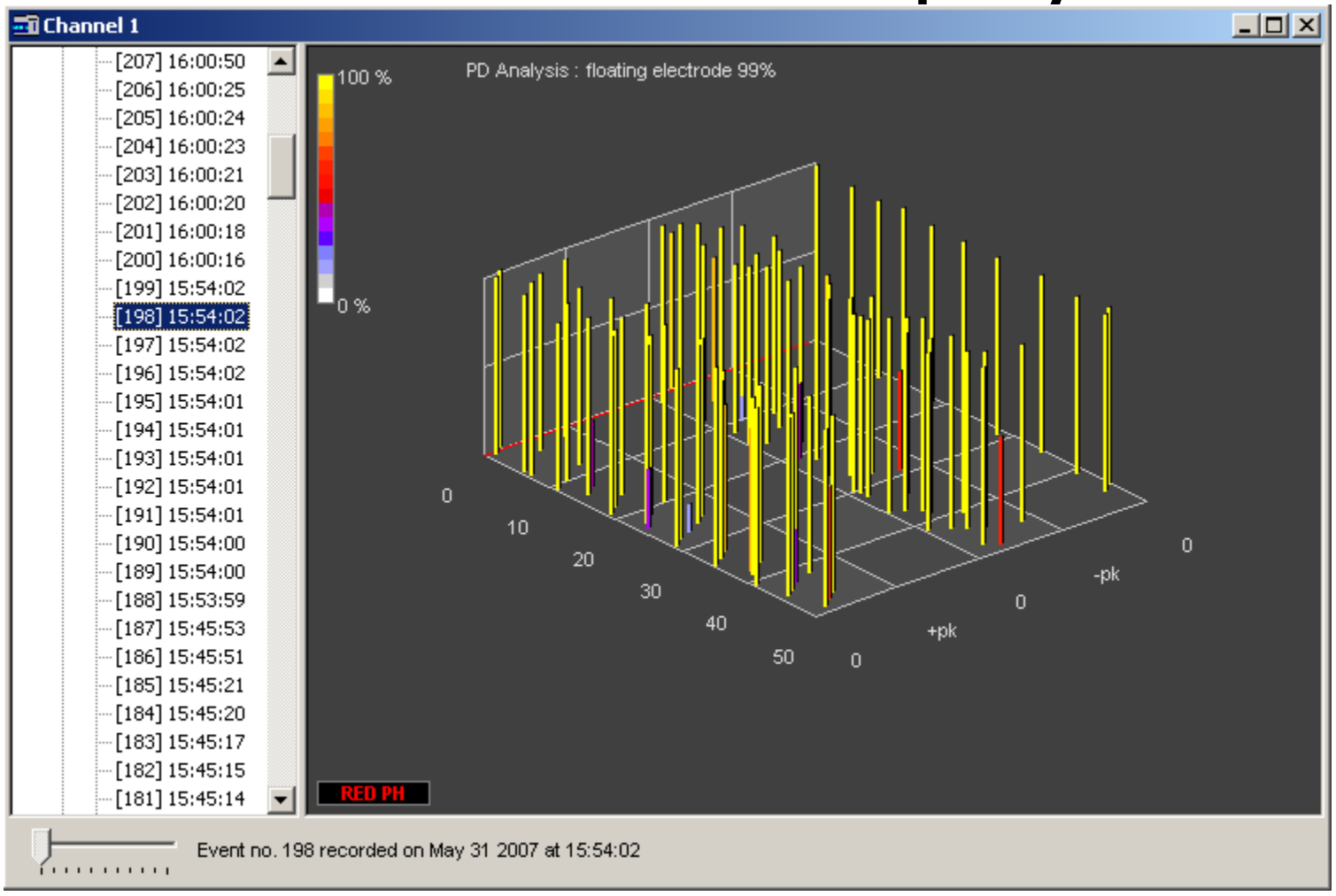
Event day display



Event day display

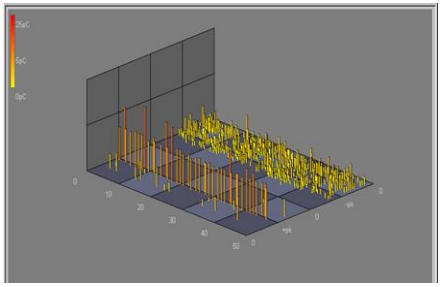


Event record display

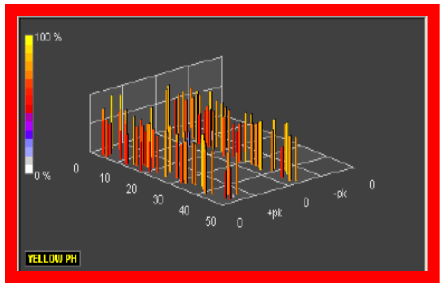


Radial PDM System Data Displays

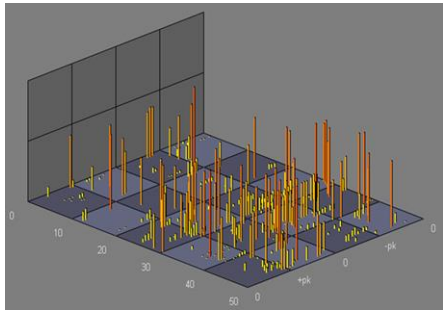
Conductor Surface



Floating Component

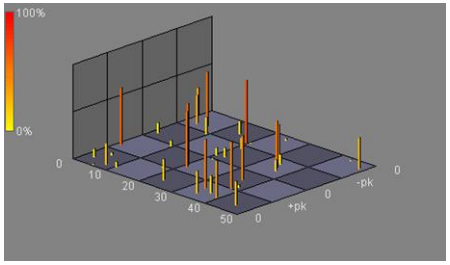


Defective Discharge Lamp



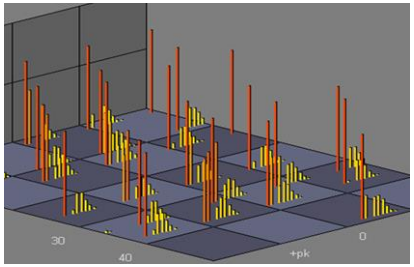
Real PD

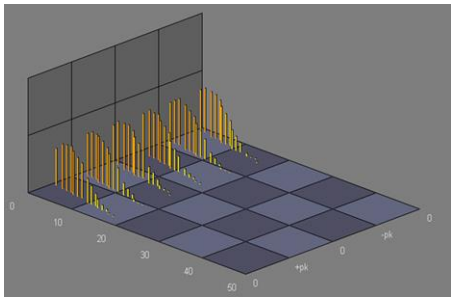
Noise



Hopping Particle

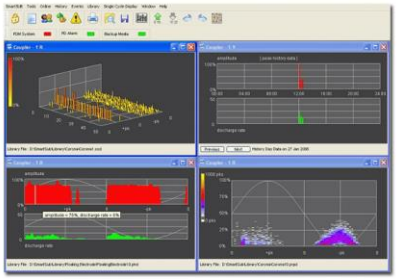
Mobile Phone





RADAR

Radial PDM Artificial Neural Network



2D + 3D discharge data

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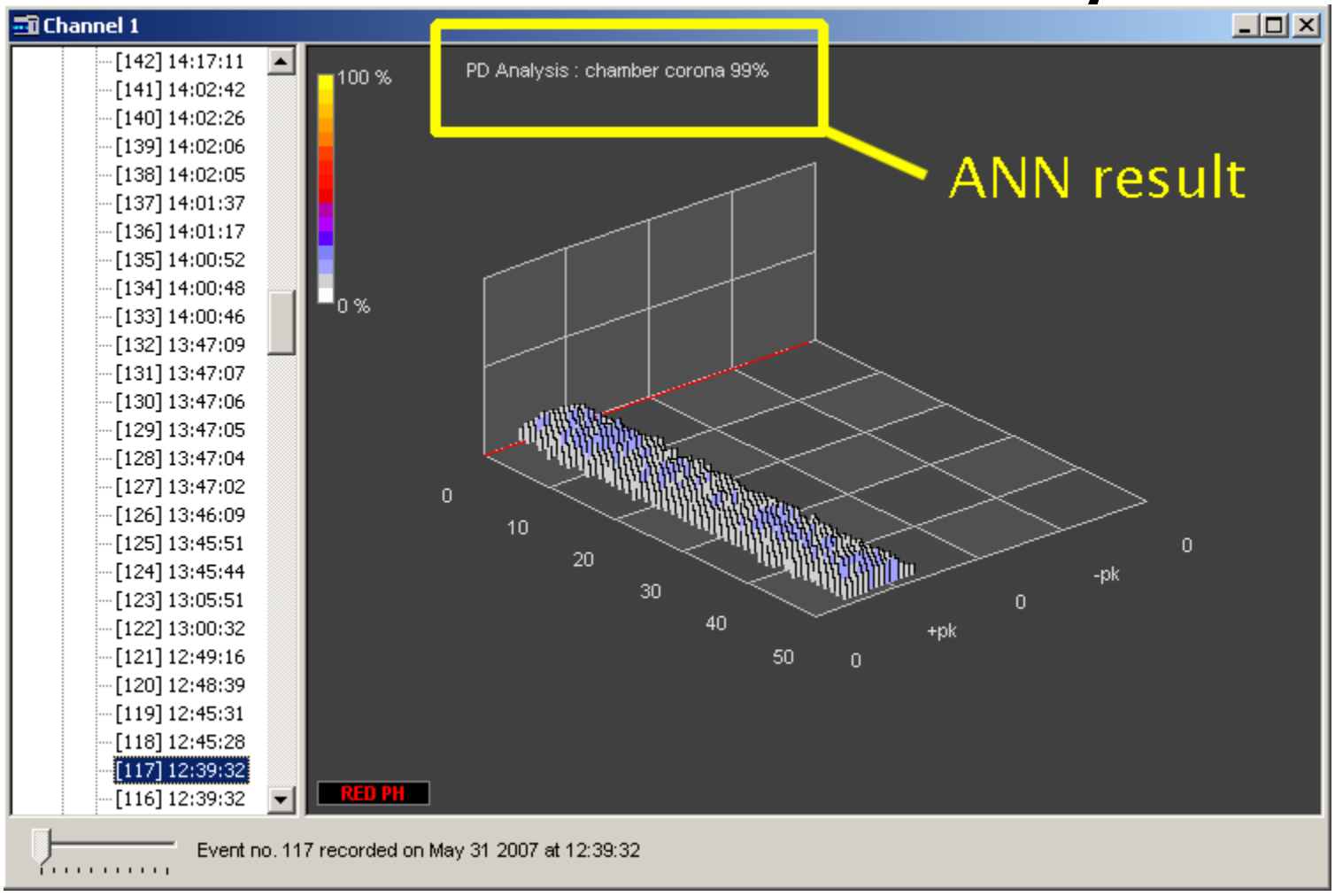
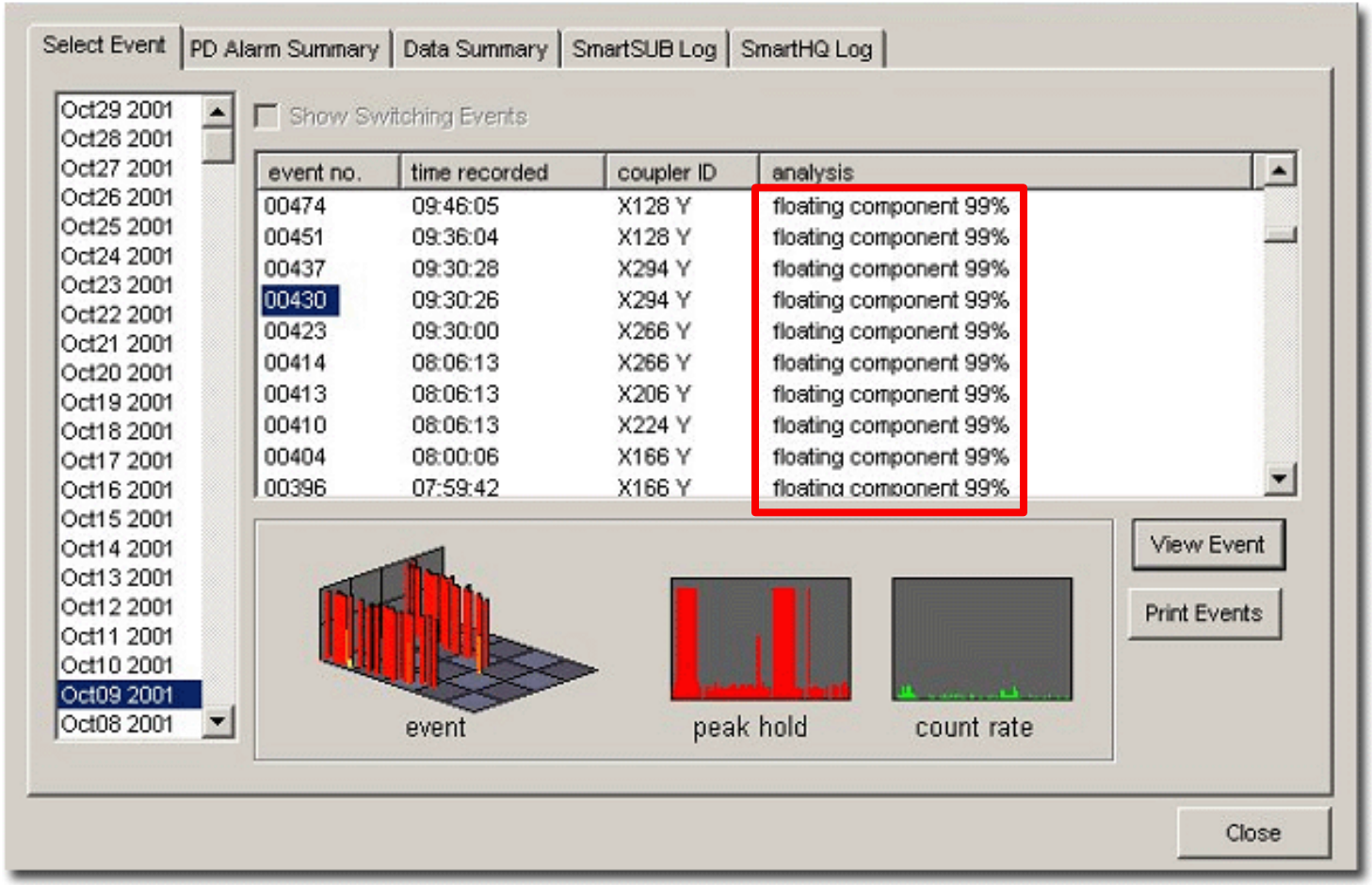
Event window with analysis



Event Window With Analysis



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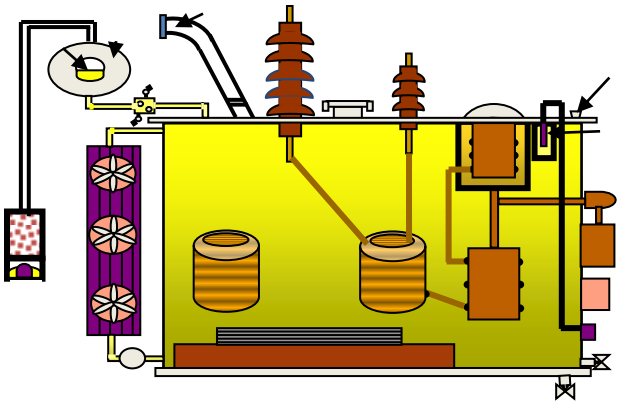
Continuous PD monitoring For Transformers (Fixed Unit)



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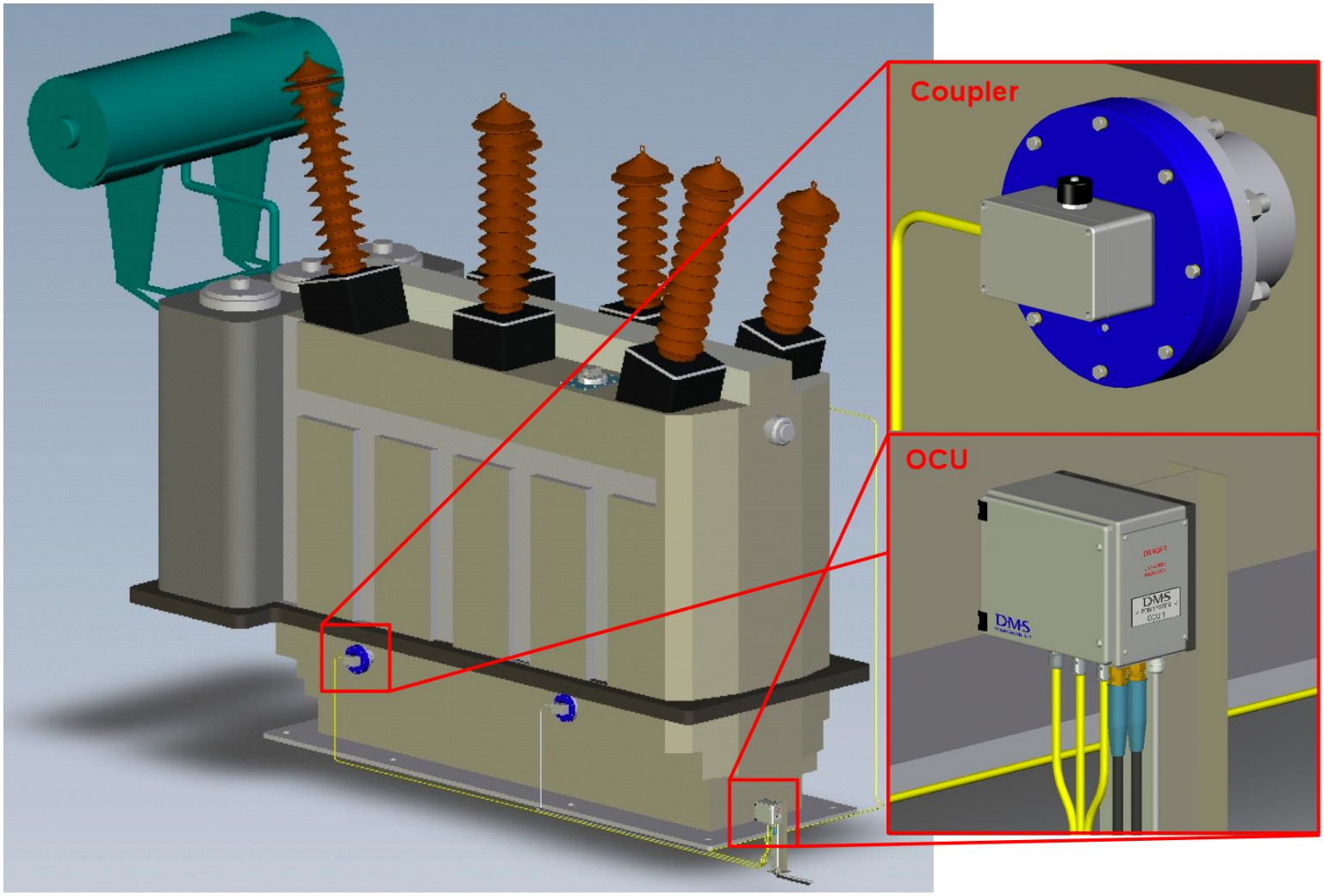
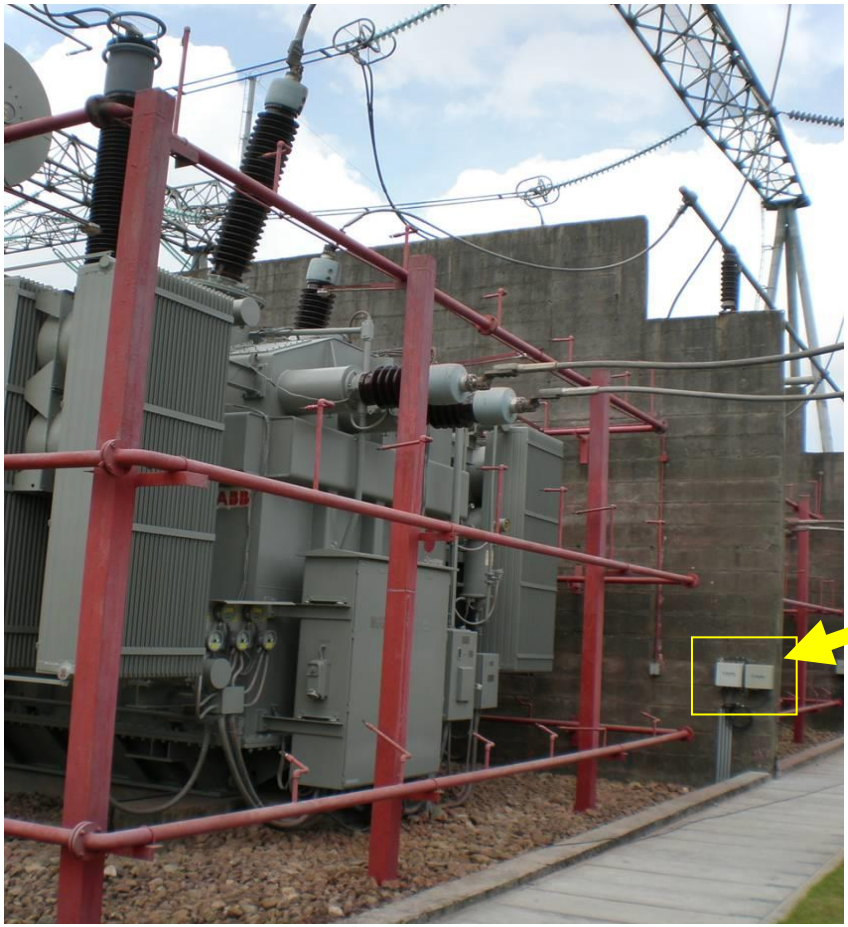
PD Sensors for Transformers



Continuous monitoring



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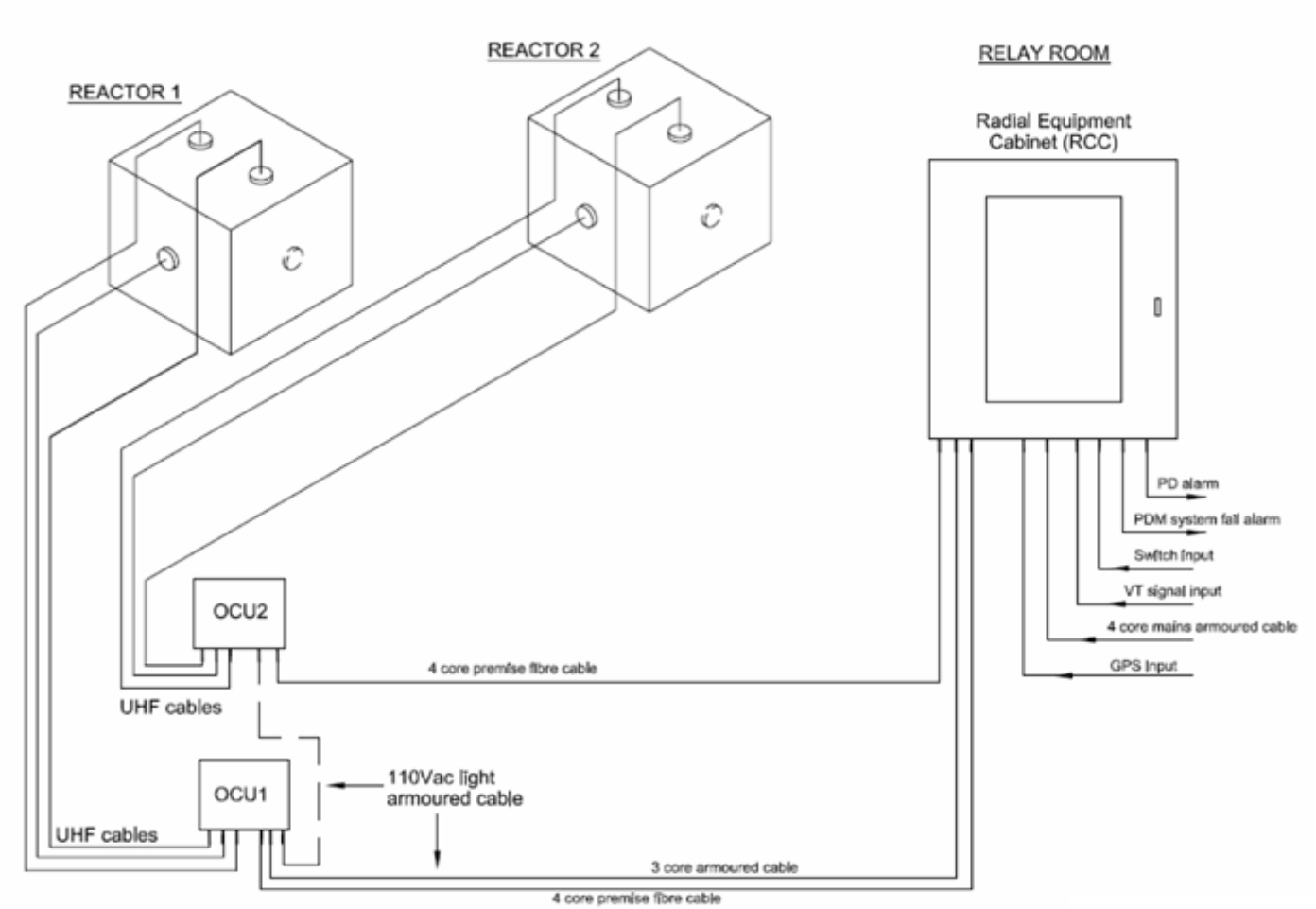
General arrangement



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PDMG-R Installed on an In-Service 400kV Reactor

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From Our Reference for PD System on Transformers

El-Tebbin Power Station
2*125 MVA
220/66/11KV

Feb. 2010

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From Our Reference for PD on Transformers

Abo-Qir Power Station
6*650 MVA
15/220KV

March
2012

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Location of PD in Transformers

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Locating PD defects in transformers

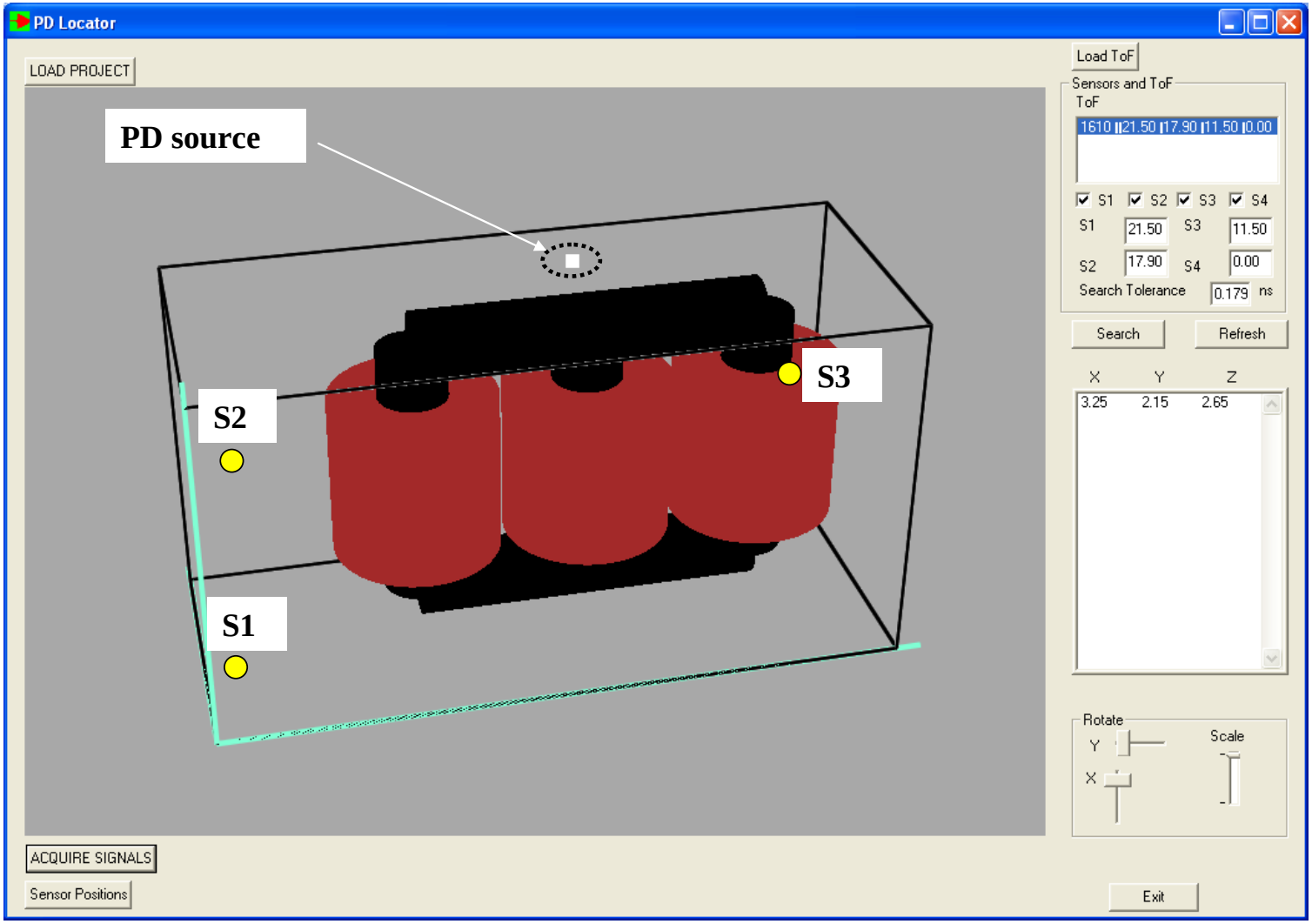
- In GIS location can be made with a commercially available high speed oscilloscope
- In transformers, the location must be 3-dimensional with the added complexity of large internal structures
- Manual location using derived timing information is very difficult
- A test instrument with custom software is being developed to simplify the location procedure

UHF PD location – Demonstration of principle

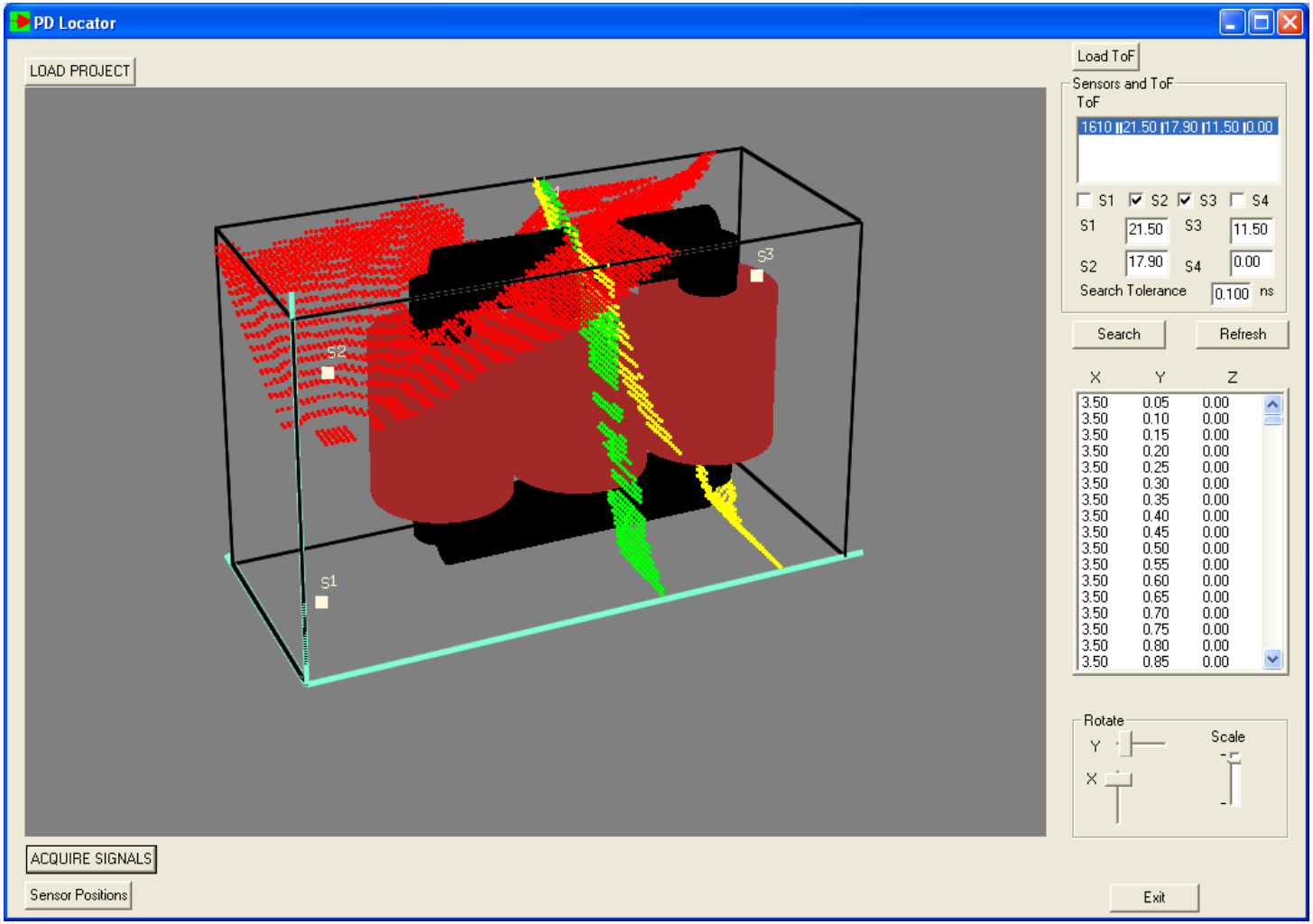
The interaction between the different planes of PD location between each pair of sensors can be illustrated through pulse injection.

In the next few slides, the DMS pulser was used to inject a pulse into the sensor S4 . . .

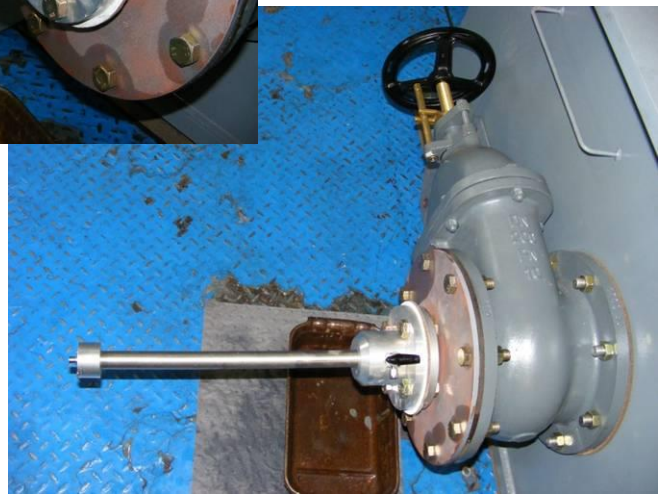
Pulse injection into S4 as the PD source



S4 pulse injection location results for three sensor pairs (S1-S2, S1-S3, S2-S3)

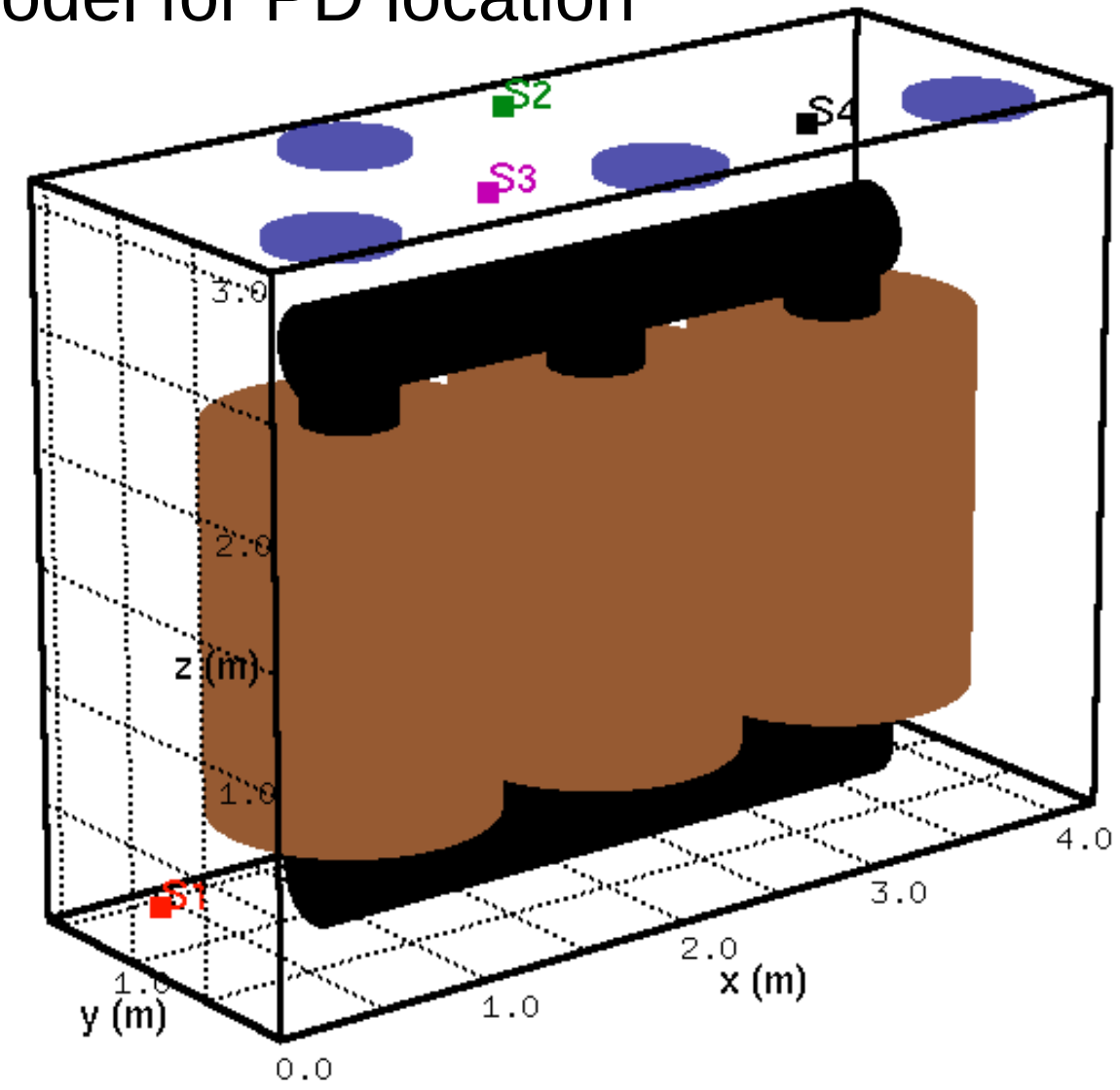


Recent example of PD Location

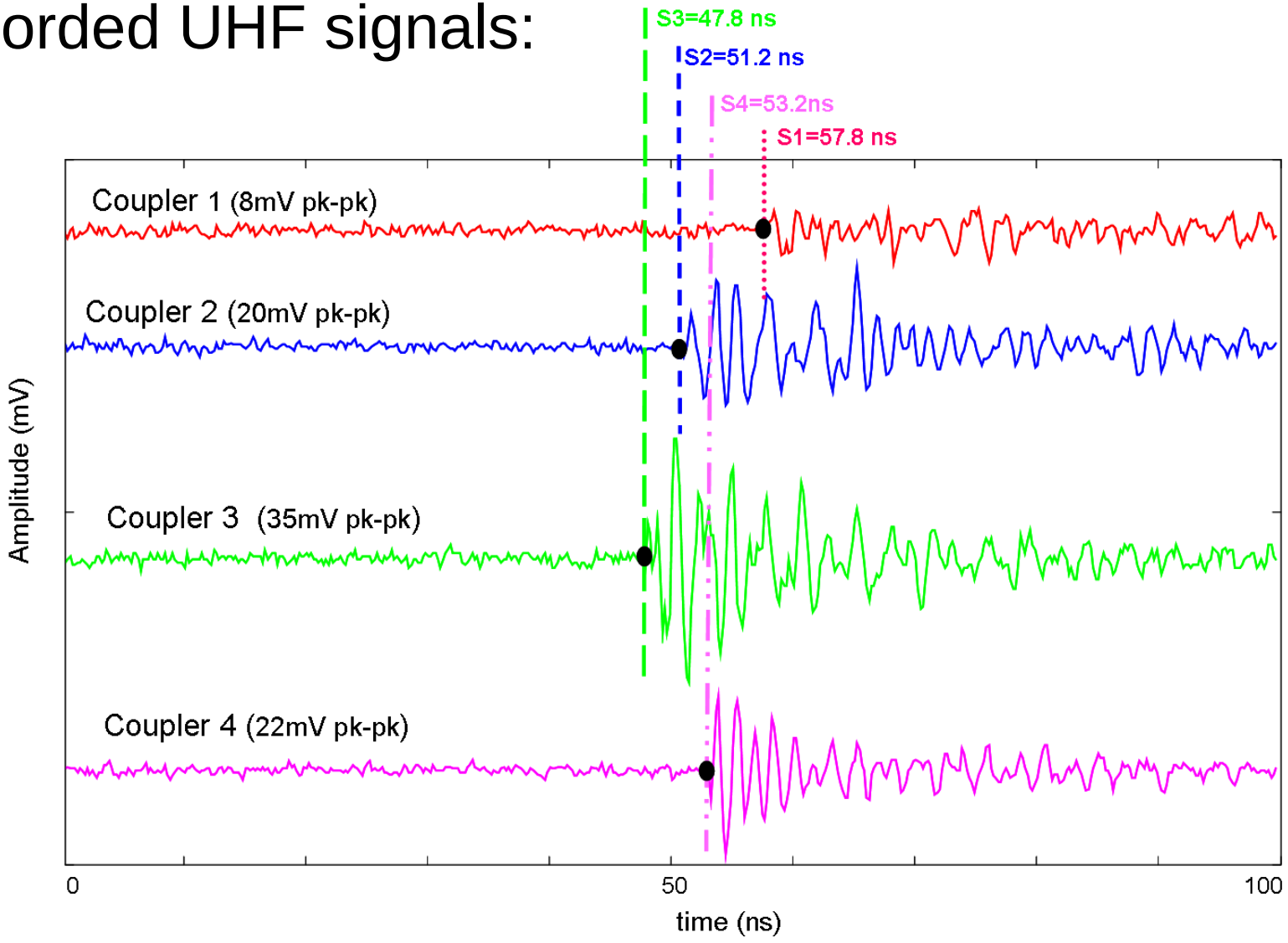


Transformer Shows PD in Factory

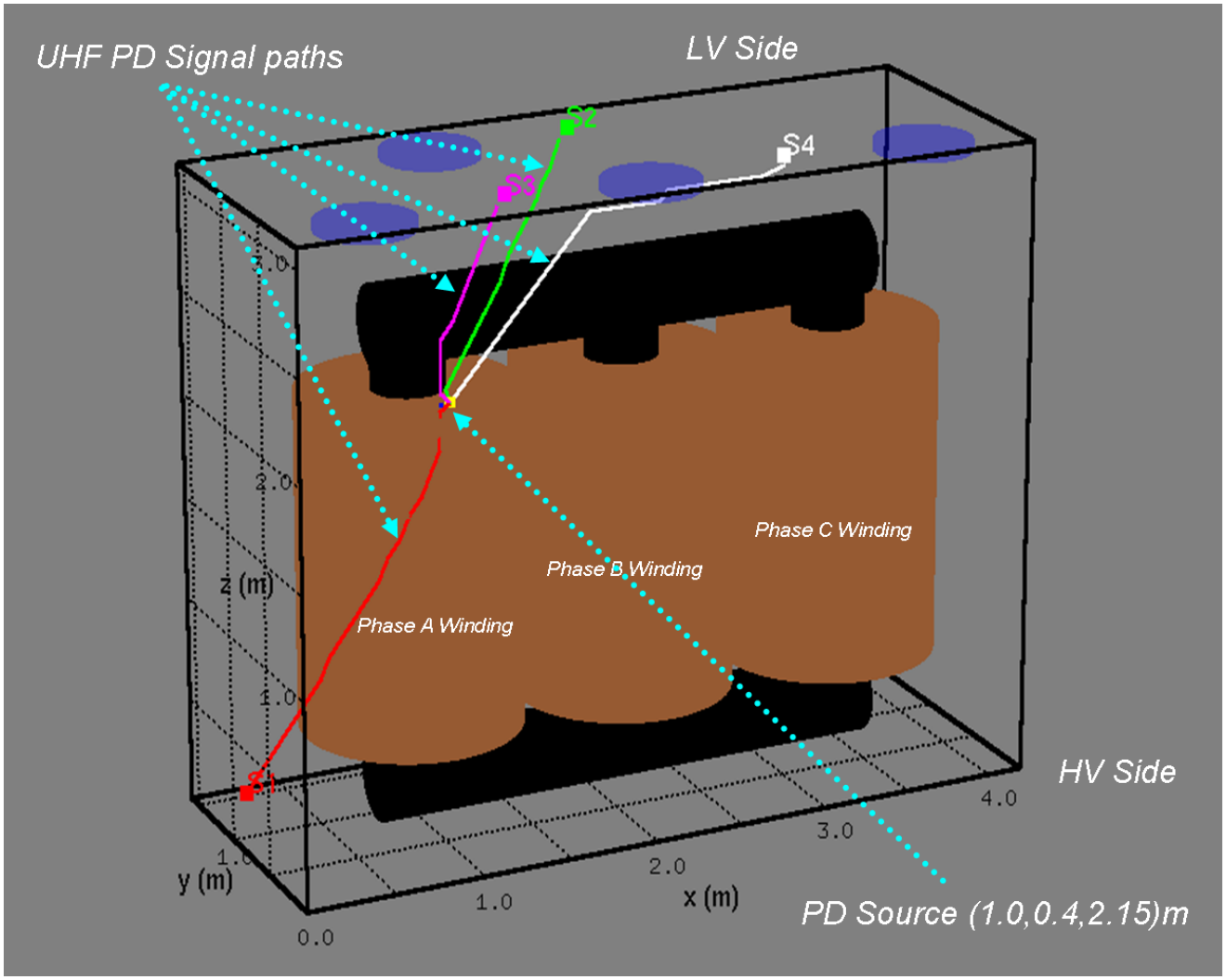
Transformer model for PD location



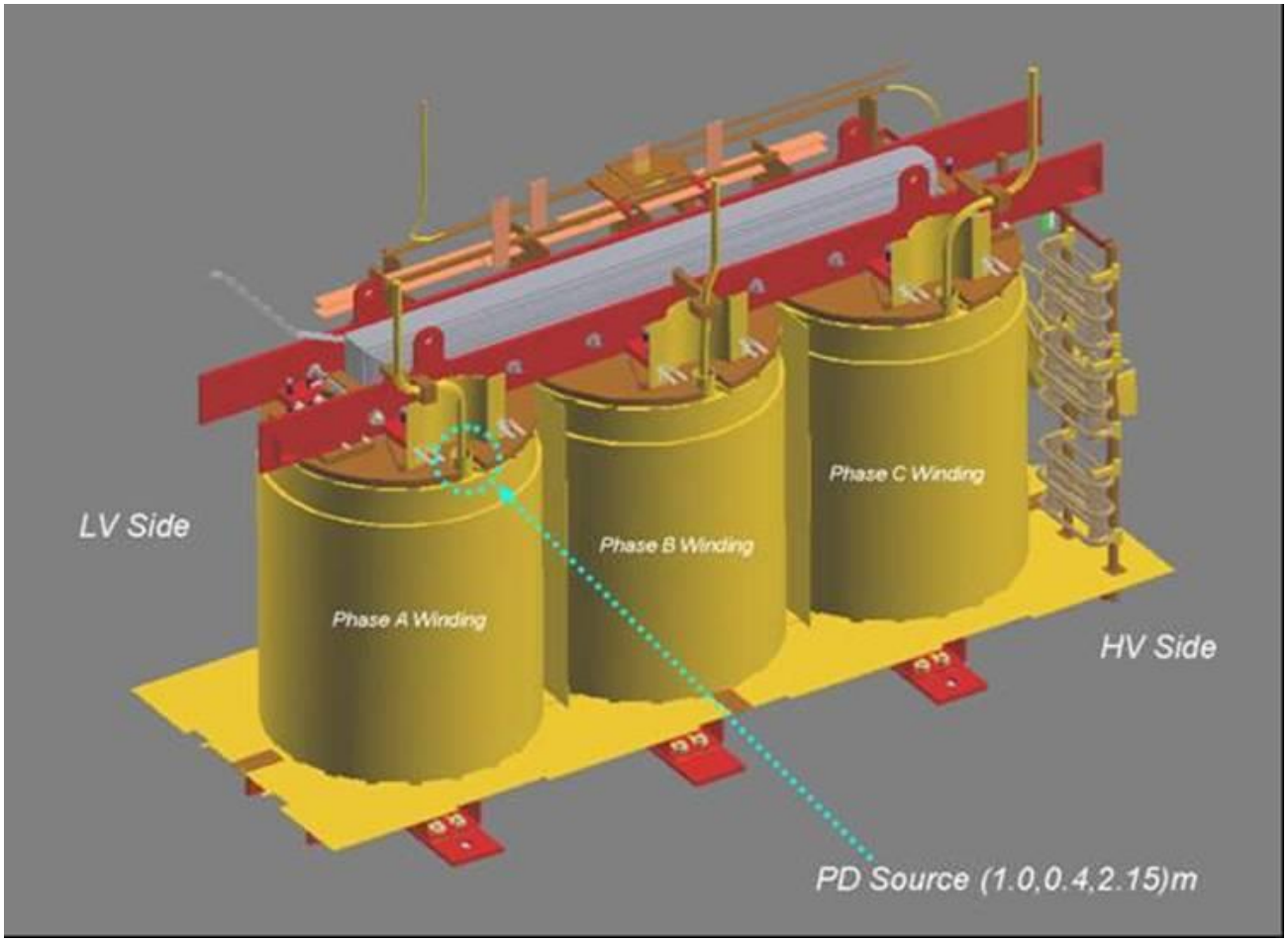
Recorded UHF signals:



PD location using the DMS system:



Manufacturer’s model



In this case, the located PD was only 200 pC during overpotential test.

The transformer passed the test.

Field Trials for Location of PD in Power Transformers

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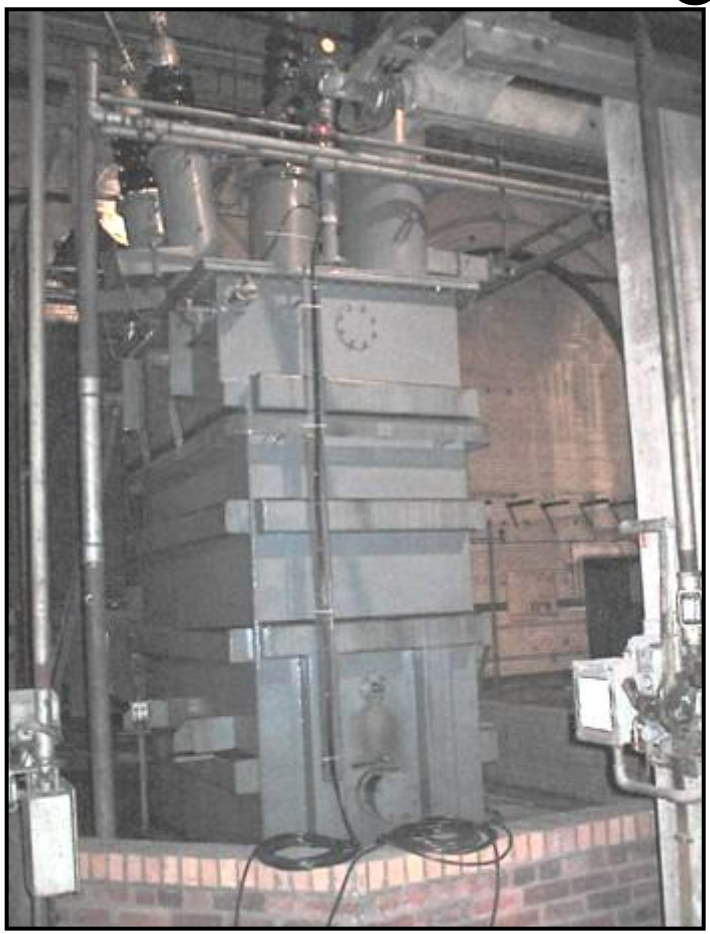
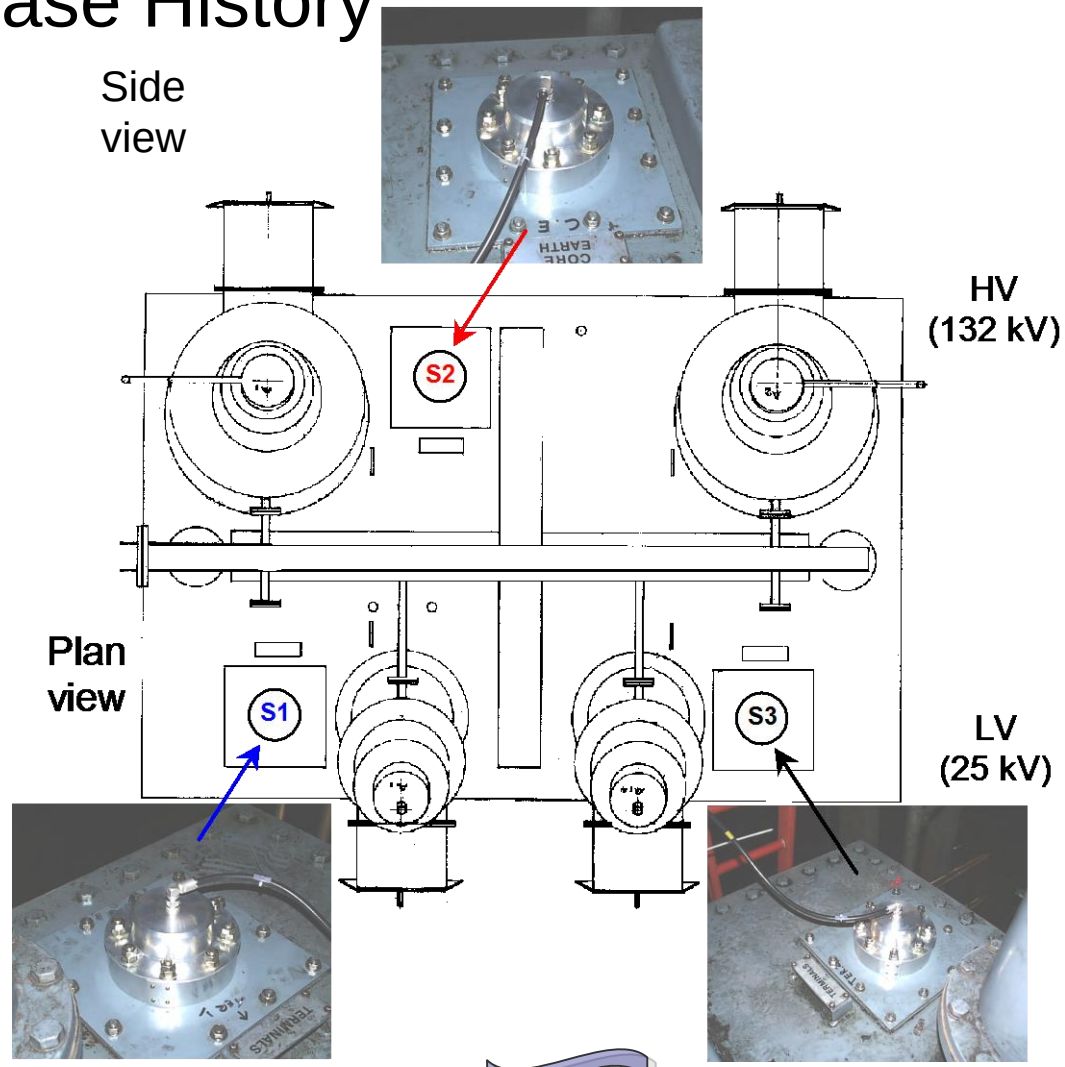
Case History

Traction Transformer:
18 MVA, Single Phase, 132 – 25 kV

- **Heavily loaded unit with increased production of hydrogen and acetylene**
- **Fitted with 3 UHF Sensorsfitted, 24 m cables**

Case History





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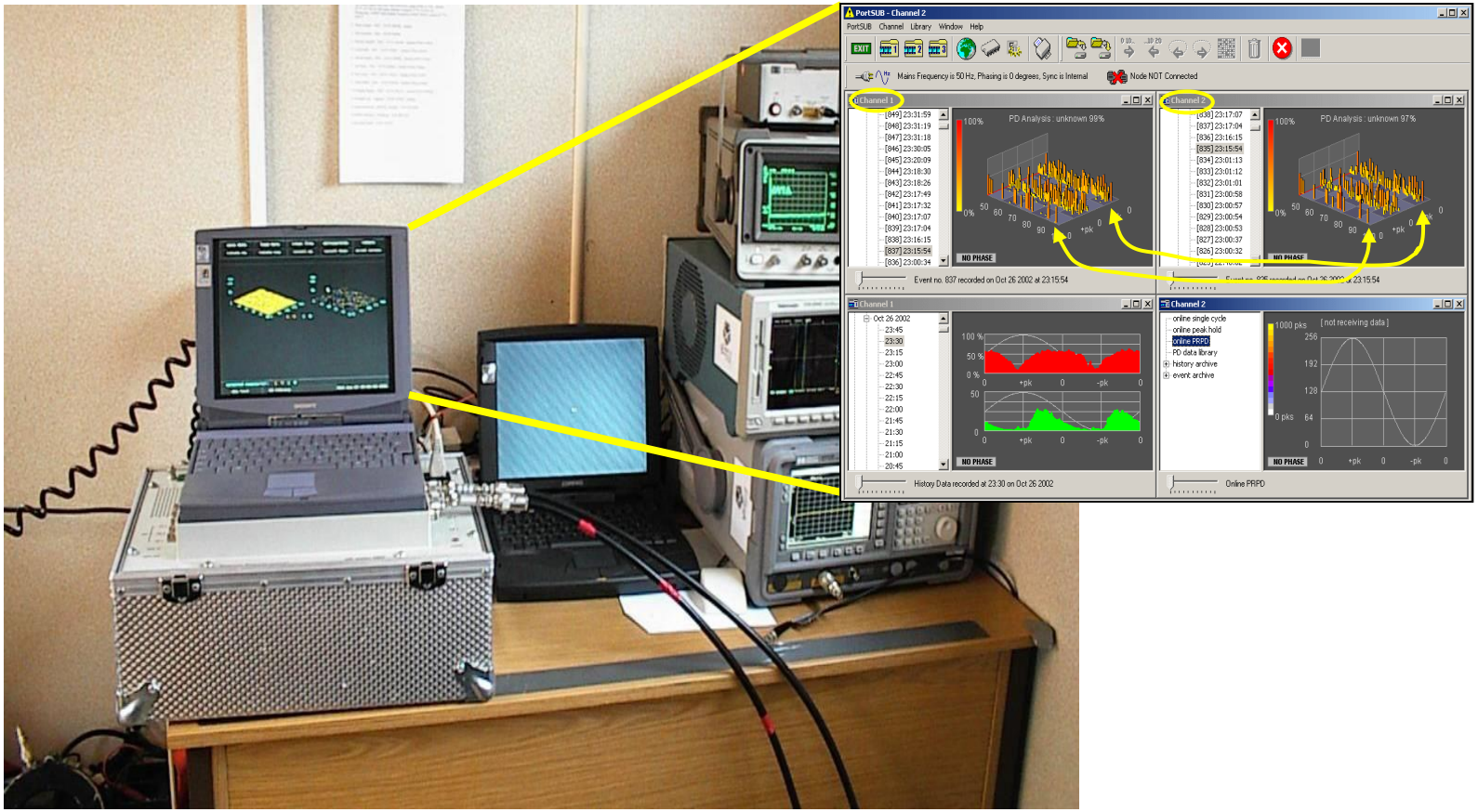
Portable Unit with High Speed Oscilloscope



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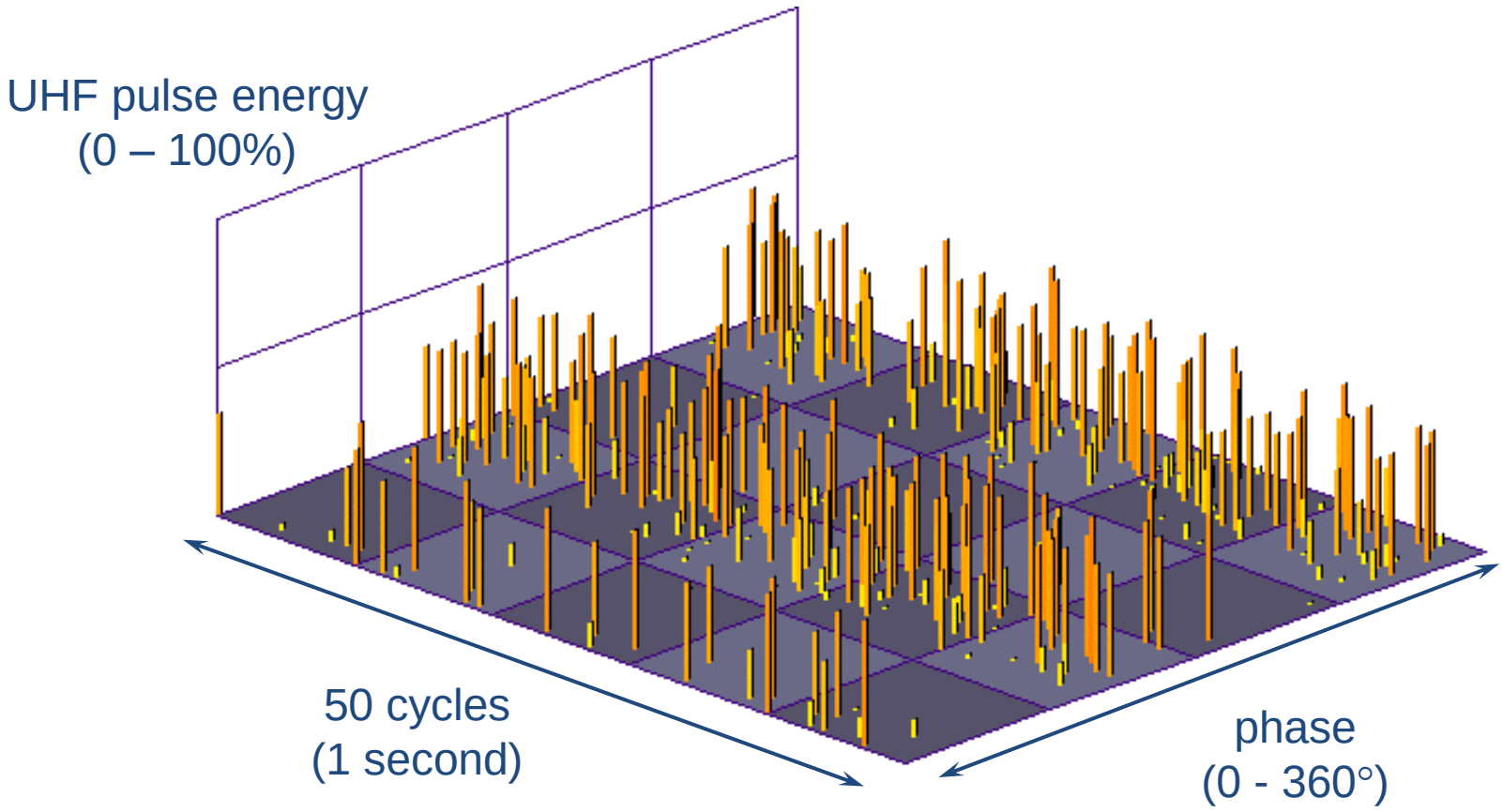
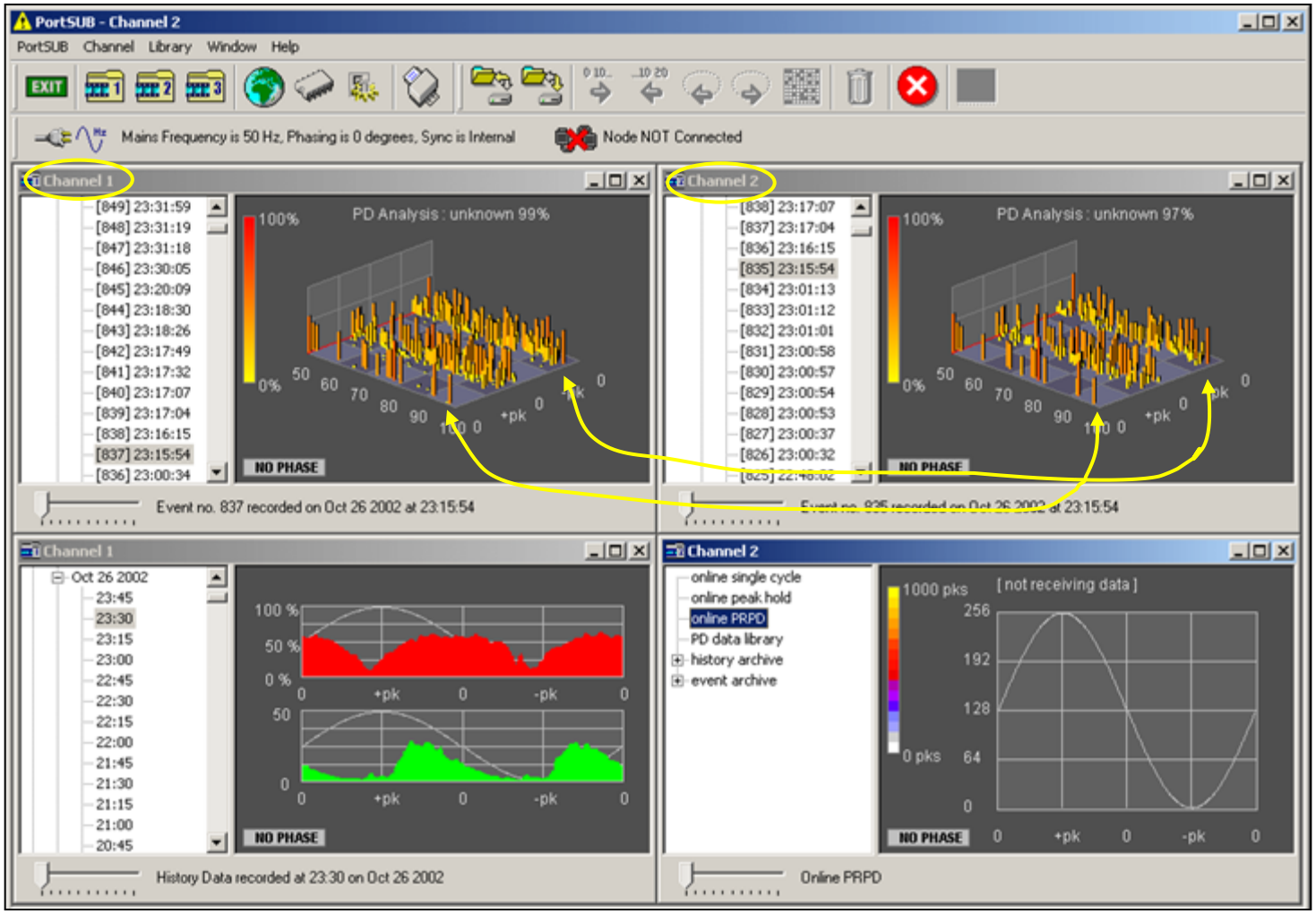
Case History



Sensor 1

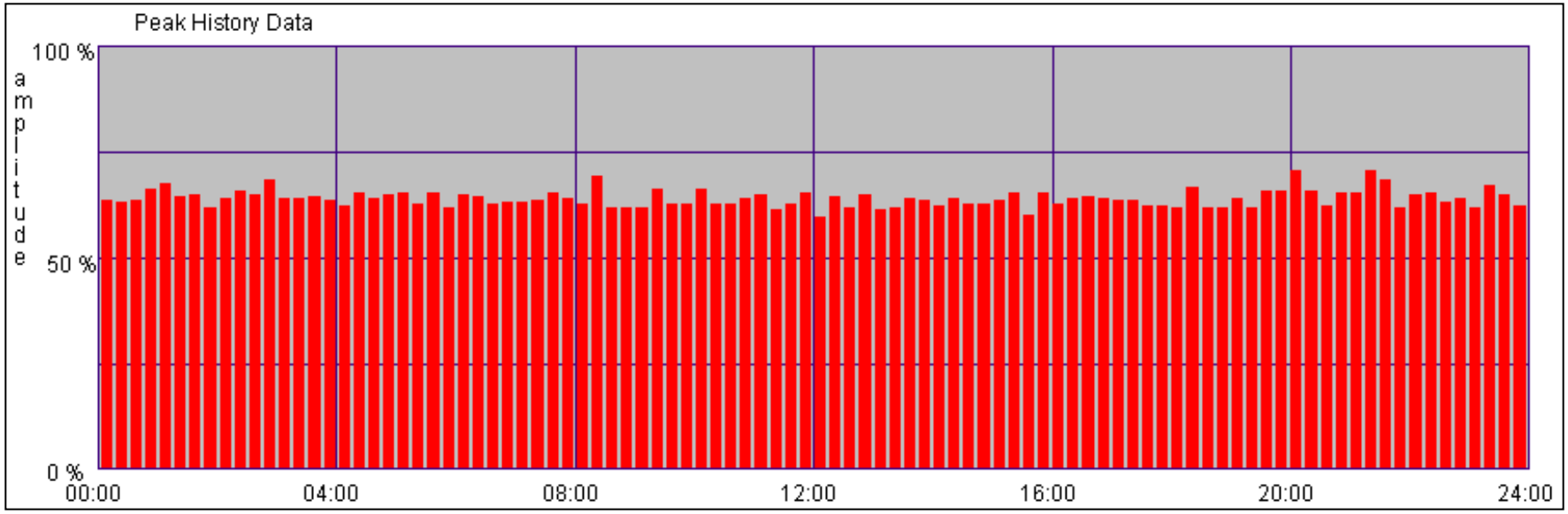
PD pattern with strong 180 degree phase symmetry

Case History



Portable UHF PD Monitor Display

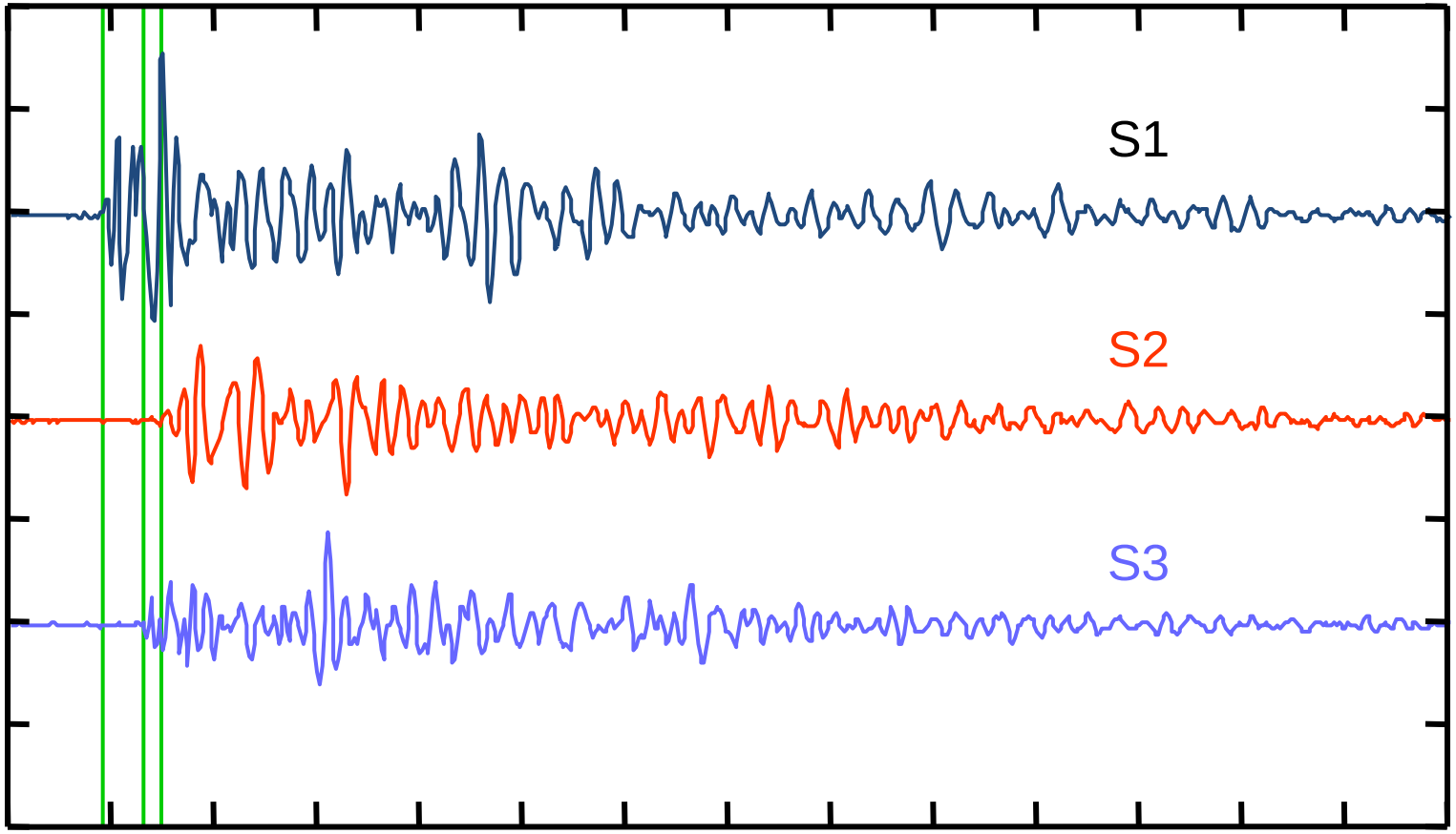
Case History



Discharge history shows constant PD activity over a 24-hour period

Case History

amplitude
(50 mV /div)

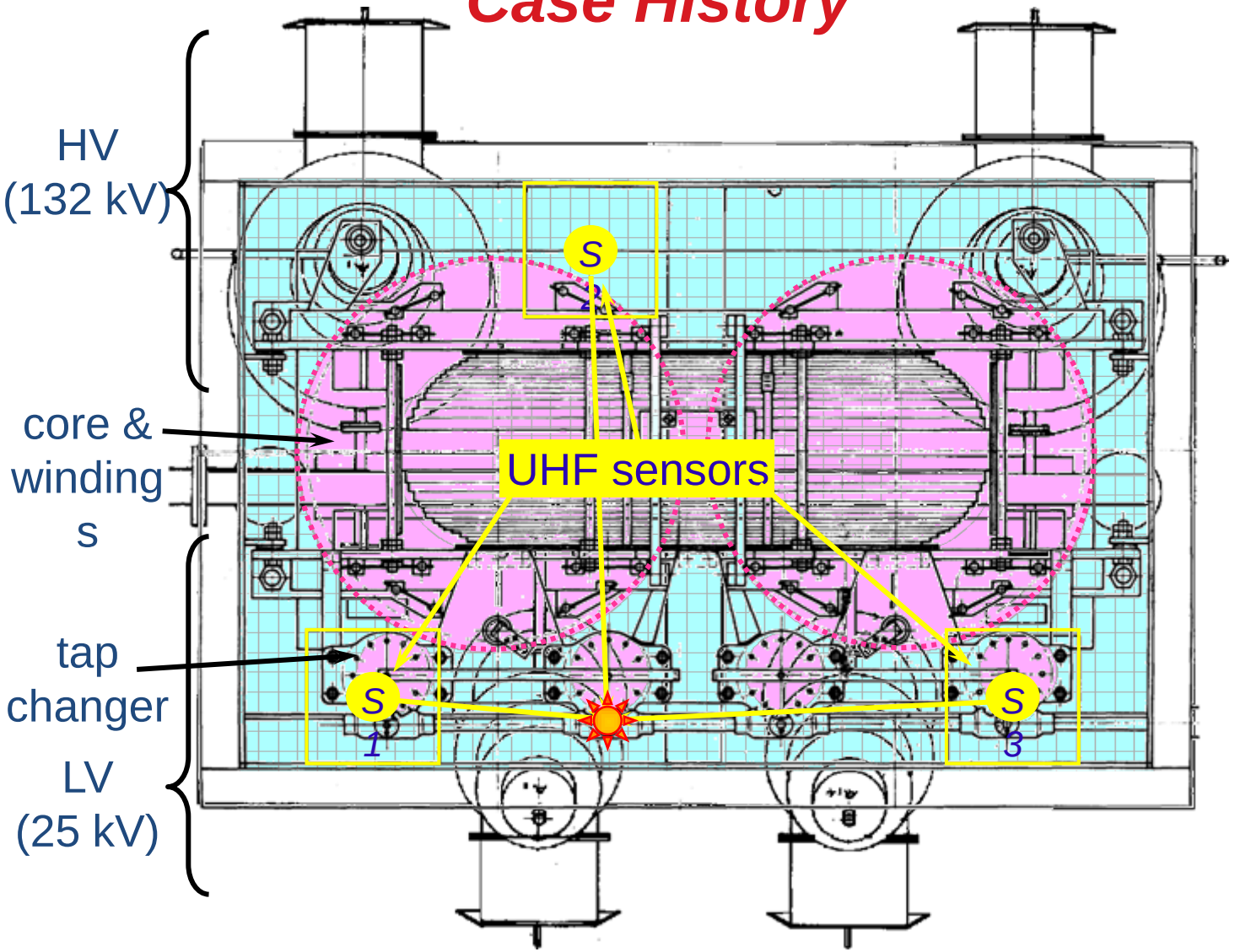


differences in time of arrival
at known sensor positions

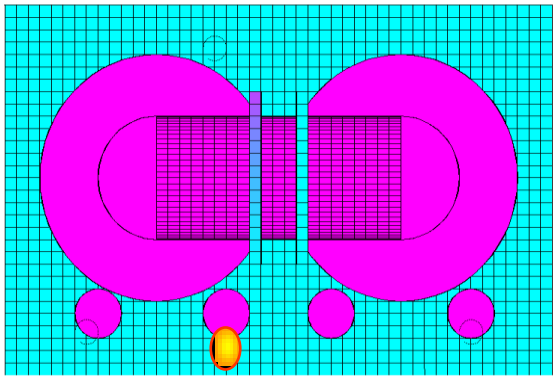
time (5 ns / division)

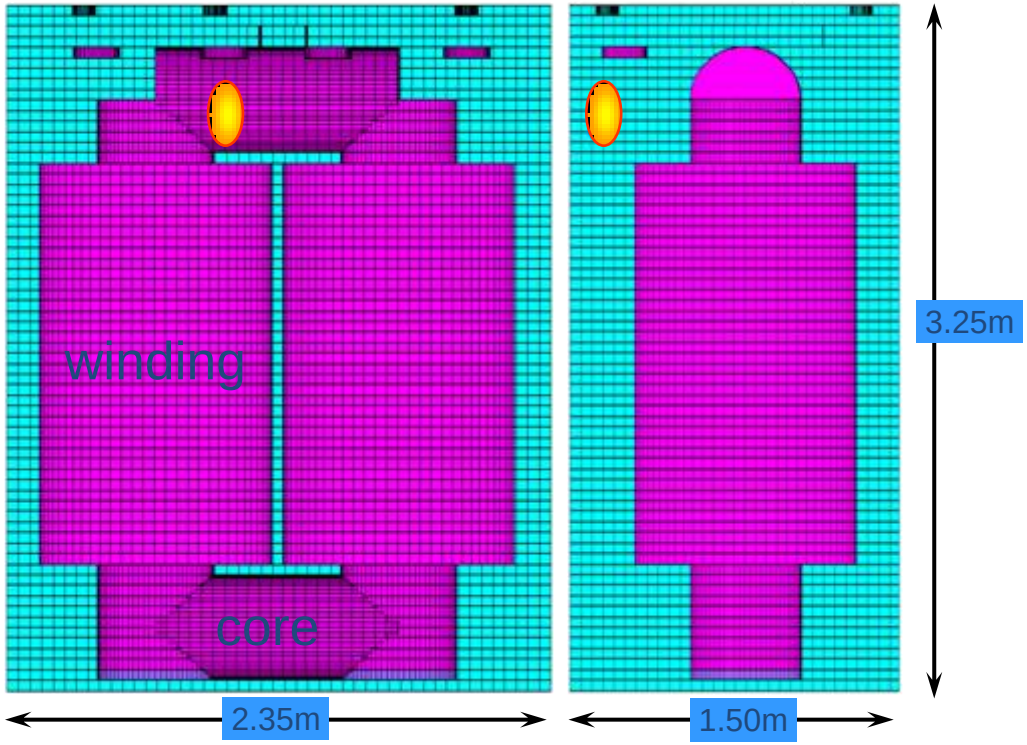
Set of UHF Signals from a Single PD Pulse

Case History



Case History

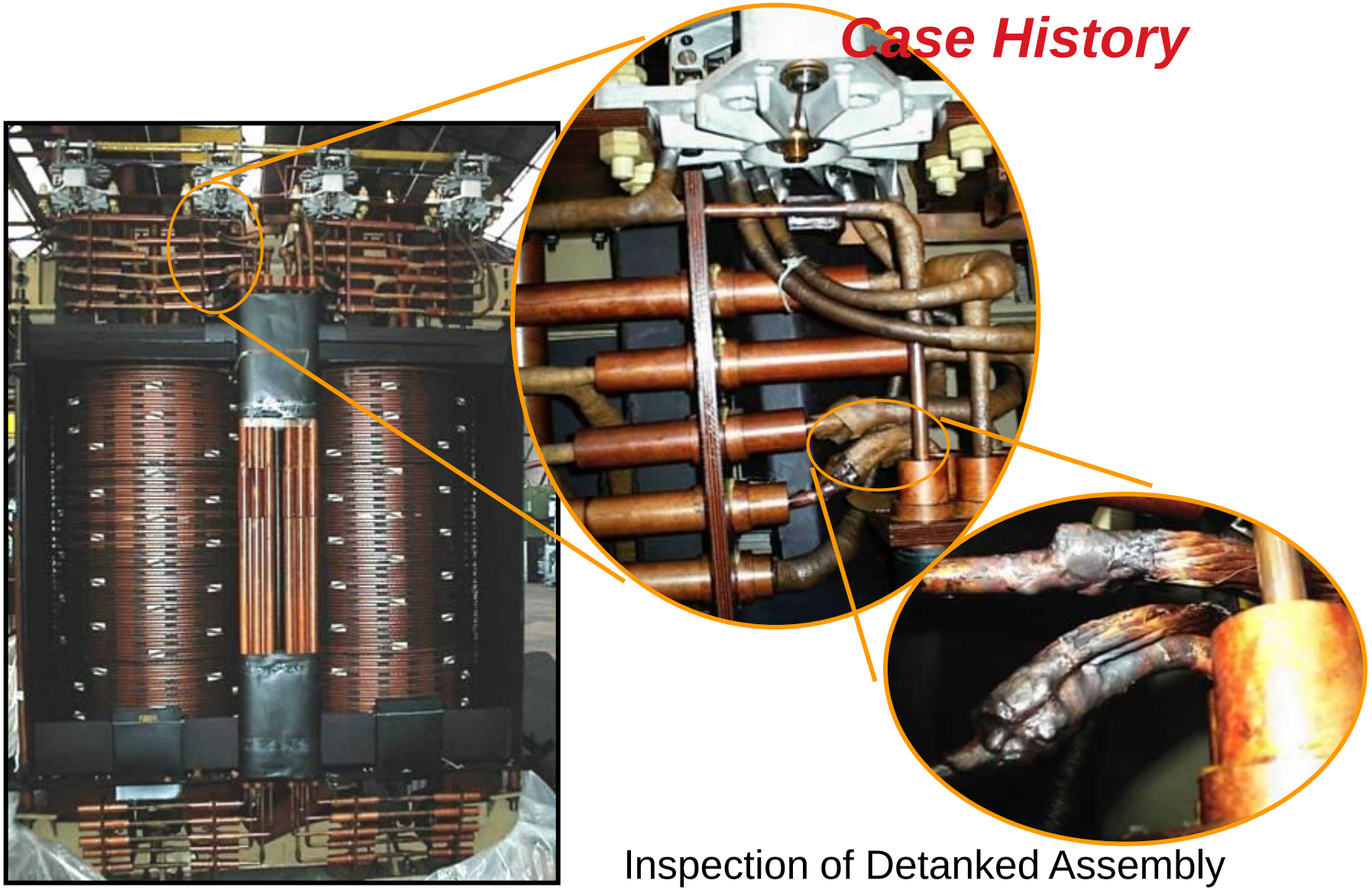




Third-Angle Projection Showing the Suspect Volume

(Mesh size = 5 cm)

Case History



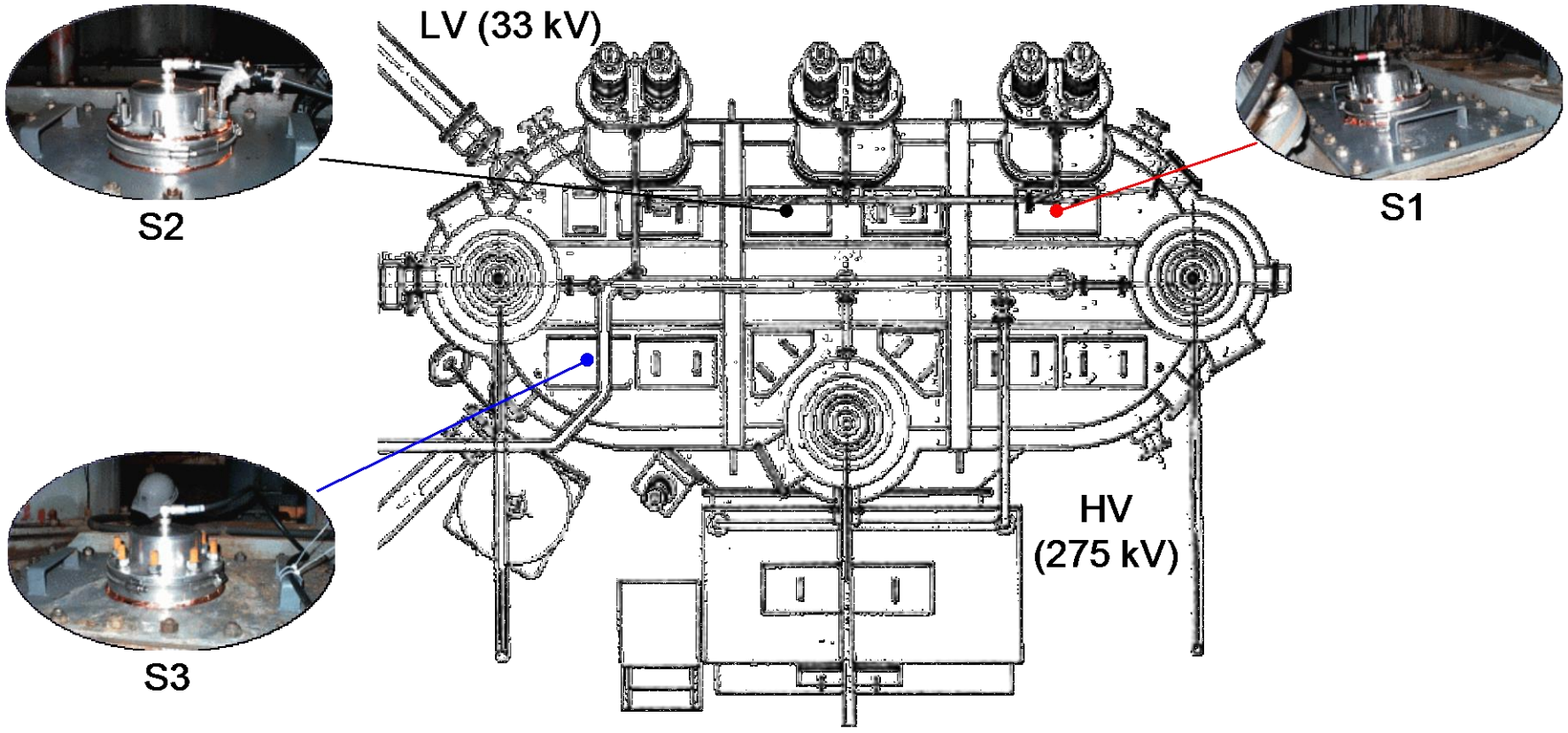
Inspection of Detanked Assembly

Case History

120 MVA, 3-Phase Transformer, 275 – 33 kV

- **Unit scheduled for replacement**
- **Abnormal dissolved gasses**
- **UHF monitor left on-site for 17 days recorded intermittent PD activity**
- **Evidence of more than one PD source**
- **No correlation between PD activity and load**
- **PDs were not active at times of site visits with equipment to locate PD**

Case History



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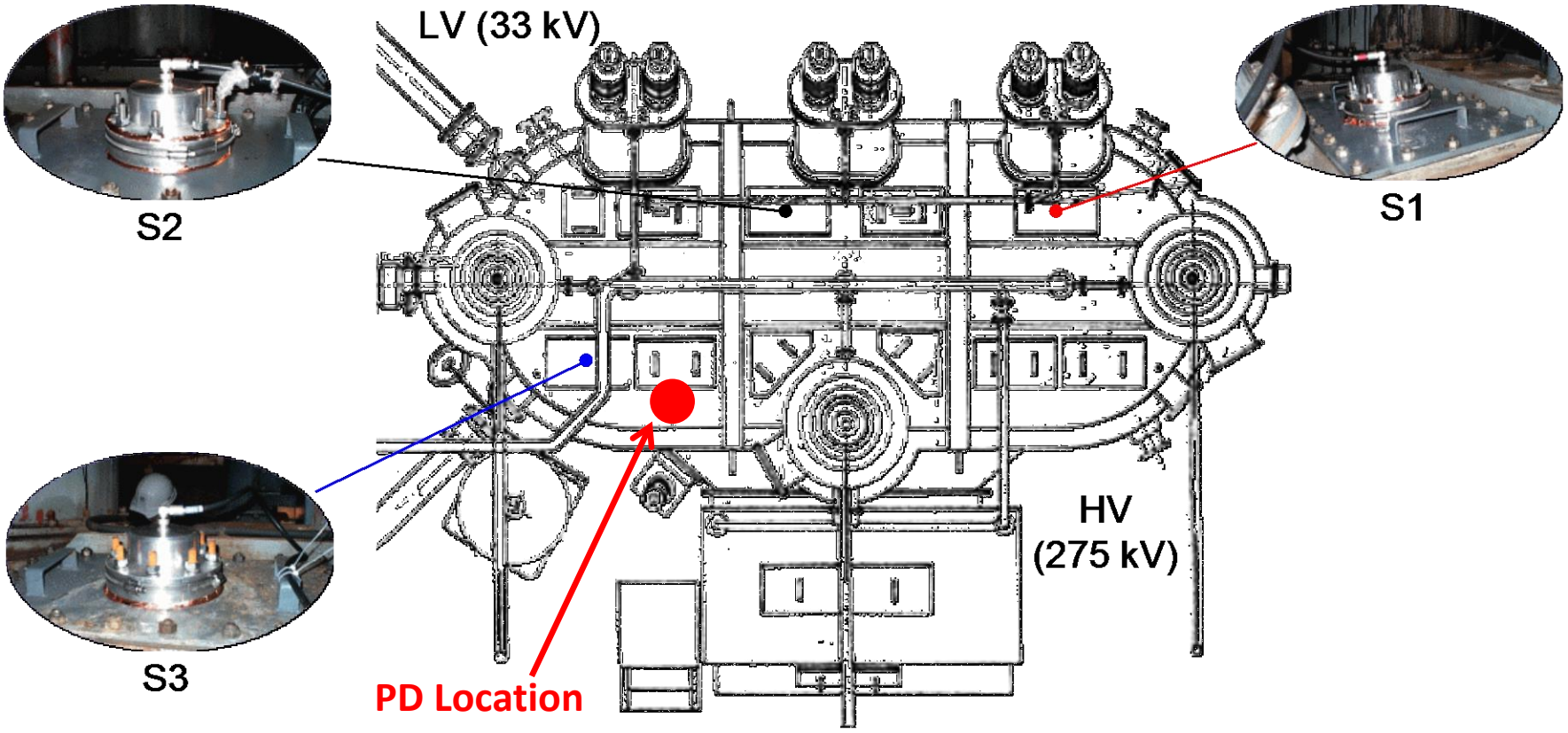
Location



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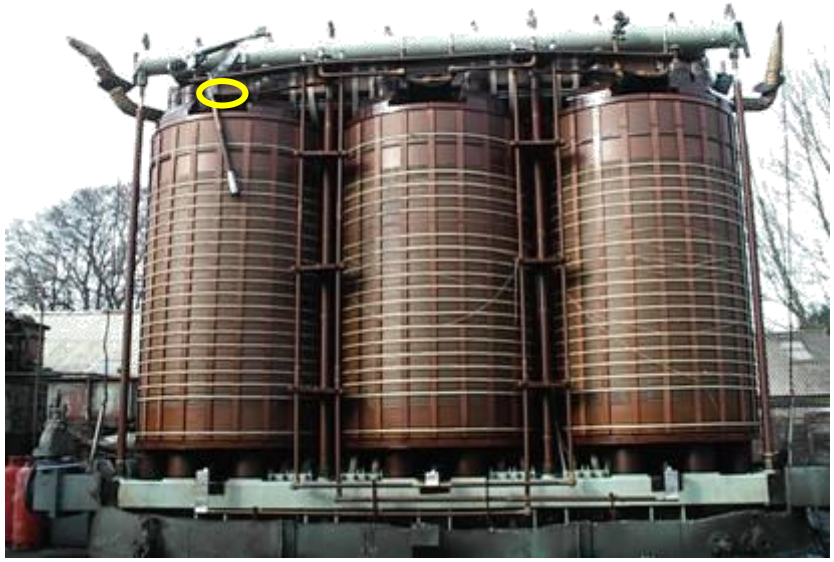
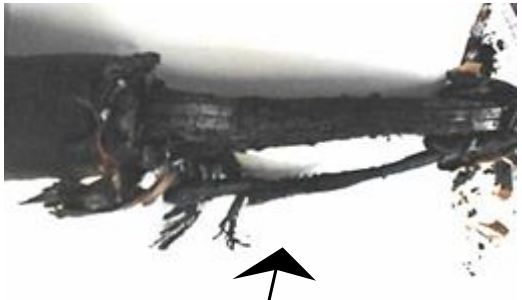
Case History



Damaged Joint
Discovered During
Disassembly



Charring on LV lead

Broken strands on
lead to LV winding

Reference List (1992-2010)

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Thanks

Thanks

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